al Disaster Survey Report 79-1



# The Disastrous Texas Flash Floods of August 1-4, 1978

A Report to the Administrator





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**ceanic and Atmospheric Administration**
eather Service

Rockville, Md.
March 1979

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Rockville, Md.
March 1979

U.S. DEPARTMENT OF COMMERCE NOAA
COASTAL SERVICES CENTER
2234 SOUTH HOBSON AVENUE
CHARLESTON, SC 29405-2413



**U.S. DEPARTMENT OF COMMERCE**
**Juanita M. Kreps, Secretary**

**National Oceanic and Atmospheric Administration**
Richard A. Frank, Administrator

National Weather Service
Richard E. Hallgren, Director

## FOREWORD

The primary goal of all National Oceanic and Atmospheric Administration, National Weather Service, warning programs is to save lives. Following every significant natural disaster, a NOAA NWS Survey Team is formed to evaluate the effectiveness of the total warning system in meeting this goal. Since the total warning system must include the National Weather Service, the media, and the community, all three are surveyed.

Even the best of warnings is of no value if it is not disseminated and acted upon. The "bottom line" is to get individuals in the threatened area to take protective action. This is the basis upon which the effectiveness of the NWS warning programs must ultimately be judged. Clearly, warning system success depends on the full cooperation of the broadcast media, local officials, and the individual public. Without this cooperation, NWS could not accomplish its warning function in Texas or, for that matter, anywhere else.

We constantly strive to improve our performance and lessen the loss of life and property in weather-related disasters. This report presents the findings and recommendations of the NWS team that surveyed the disastrous Texas flash floods of early August 1978.

Richard E. Hallgren
Director (Designate)
National Weather Service

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# PREFACE

The following NOAA National Weather Service (NWS) Survey Team reviewed the Texas flash floods of early August 1978:

Earl W. Estelle, Team Leader and Chief, Public Services, NWS Headquarters, Silver Spring, Maryland.
Carl Reber, Executive Officer, NWS Southern Region Headquarters, Fort Worth, Texas.
H. Michael Mogil, Disaster Preparedness Staff, NWS Headquarters.
Michael Sullivan, Office of Hydrology, NWS Headquarters.
Dennis McCarthy, Lead Forecaster, Weather Service Forecast Office, Indianapolis, Indiana.

Team members began the field survey on Monday, August 7 -- 4 days after the last victim drowned. The field phase was completed Friday, August 11. Three main areas were covered: (1) internal NWS operations, (2) role of the broadcast media, and (3) community preparedness and individual public response. The survey was limited to those counties with known fatalities. Gillespie County was not visited by the team as the team did not find out about the deaths that occurred there until the following week.

The Southern Region quickly organized a special team to conduct a field search for verification of rainfall from unofficial and previously unreported sources--customarily referred to as a bucket survey. Robert S. Ellis of RFC Fort Worth lead the team comprised of Substation Network Specialists Wilburn R. Peterson, Lubbock; Robert W. Manning, Fort Worth; and John R. Lambert, Waco. They were assisted by representatives of the U.S. Soil Conservation Service, U.S. Geological Survey, and Bureau of Reclamation.

Private weather modification operations were conducted northeast of Abilene during the period of the heavy rains in central Texas. An analysis of the possible impact of these activities in enhancing rainfall amounts is beyond the scope of this report and will not be addressed.

The team was assisted by and is indebted to many individuals in and out of the National Weather Service whose help proved invaluable. In particular, the team wishes to thank all who freely cooperated by consenting to interviews and by volunteering information.

The cover photograph of the Guadalupe River at the height of the flash flood is through the courtesy of the Kerrville Daily Times, Kerrville, Texas.

# EXECUTIVE SUMMARY

## REPORT TO THE ADMINISTRATOR ON THE DISASTROUS TEXAS FLASH FLOODS

Remnants of Tropical Storm Amelia moved inland over the south Texas coast on July 31, 1978. Abundant moisture from the storm, in combination with other meteorological factors, resulted in record rainfalls over portions of the picturesque Hill Country and Big Country areas of Texas (figure X.1). Between August 1 and 3, locations in the Hill Country received over 30 inches of rain. During August 3 and 4, Big Country locations received similar large rainfalls. A 12-hour point rainfall total of 28 inches in Shackelford County of the Big Country far exceeds the 100-year return period, 12-hour rainfall value of 7.5 inches. Over the Hill Country, 21 inches fell in one 12-hour period compared to the 100-year return period value of 8 inches. No one really knows, but the return period in such cases is surely several times the 100-year return period.

The heavy rains produced extraordinary runoff values in what are usually gentle creeks, rivers, and dry washes. Most of the life-threatening runoff was in the form of flash flooding.

Overall, the total warning system (which includes NOAA, media, and the communities involved) operated well. Indeed, the NOAA part of the warning system probably worked better than we should expect it to work considering the many limitations which exist in equipment, communications, personnel, and weather observing and forecasting technology.

Even so, 33 people died--27 in the Hill Country and 6 in the Big Country. The Hill Country flash flooding peaked during the early morning hours--the worst possible time from the point of view of data collection, warning dissemination, and community reaction. Fortunately, the killer Big Country flash flooding occurred during the evening and early night, and this probably accounts for a significantly lower death toll.

Property damage has been estimated to be in the tens of millions of dollars. While this figure is not overly excessive by itself, it is high when considered in relation to the population density of the areas affected.

The Survey Team, as the result of onsite inspections and interviews, submits the following findings and recommendations. In doing so, we readily admit that most of the ideas presented below are not new--by and large, the same weaknesses have been found in several other similar surveys.

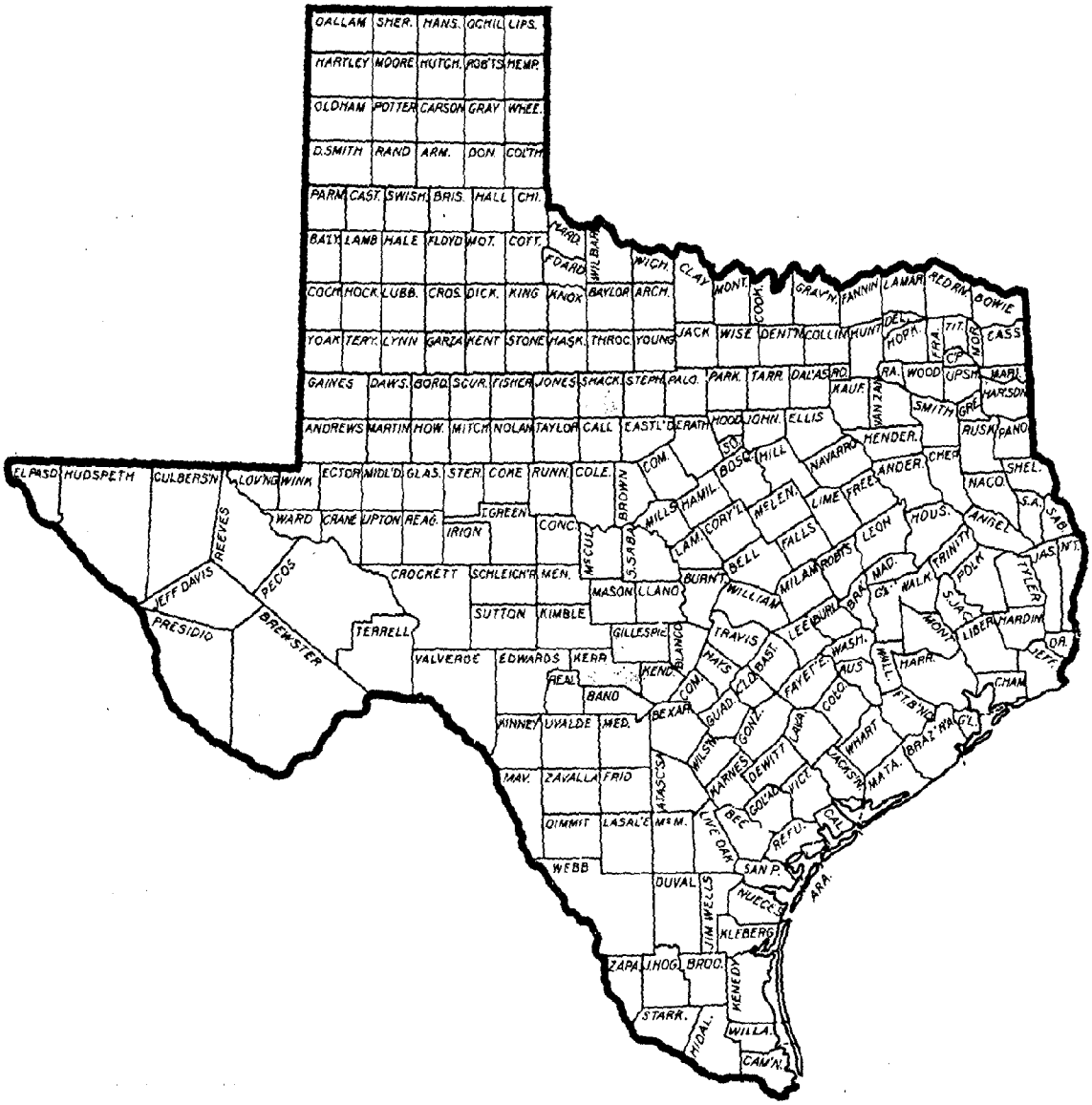


Figure X.1 -- Flooded Hill Country Counties and the Big Country County. (Shaded)

## FINDINGS AND RECOMMENDATIONS

### Finding 3.1

There were not enough real time river and rainfall reports available to NWS during and after critical river crests because of (1) the lack of automatic stations and (2) breakdowns in landline communications.

### Recommendation 3.1

Much more effort should be directed toward automation of the river and rainfall reporting networks through AHOS/S and similar automated systems. Existing official rainfall networks should be supplemented with volunteer, unofficial stations using existing storm spotter networks, such as now operated by amateur radio operators and other cooperators.

### Finding 3.2

Radar data, while not providing precise rainfall measurements, were invaluable to the NWS in its warning efforts. NWS employees, particularly those at Hondo and Abilene, performed outstandingly under difficult circumstances.

### Recommendation 3.2

Every effort should be made to provide field forecasters with even better radar estimates of rainfall rates. (Note: The RADAP program funded by the Congress in FY 79 is expected to make a major contribution in this regard.)

### Finding 3.3

There was some loss in the quality of the radar data available to San Antonio via the WBRR radar remote readout because of frequency instability in the basic radar set at Hondo.

### Recommendation 3.3

National Weather Service should make every effort to collocate radars and NWS offices with warning responsibility. Efforts should be made to obtain improved remote radar displays where collocating is not possible and to accelerate the implementation of RADAP.

### Finding 3.4

Radar summaries are widely read by the media and are an additional way of advising them (and the public) of the status of watches. While there is no firm requirement to do so, some radar summaries headlined the existence of a flash flood watch. However, most did not.

Recommendation 3.4

National Weather Service should consider the desirability of requiring that current flash flood (or severe storm) watches be headlined in radar summaries when watches include part of the 125-nautical mile surveillance area.

Finding 3.5

The Stephenville radar failed during the critical period. It had had a history of relatively poor performance.

Recommendation 3.5

NWS should investigate and correct Stephenville radar downtime problems.

Finding 3.6

Geostationary Operational Environmental Satellite (GOES) data and the Kansas City SFSS played a very useful role in helping forecasters to understand the nature of the weather system causing the heavy rains. However, the satellite-derived rainfall estimates in this particular meteorological situation involving abundant moisture and generally low cloud tops, while showing heavy rainfalls, were generally too low. Nevertheless, they did correlate with the heavy rain areas. In the case of the Albany flooding, the 0100 GMT August 4 Satellite Interpretation Message (SIM) discussed active convection in the general area, but the satellite data did not indicate flood-producing rains until several hours after the first flooding struck Albany.

Recommendation 3.6

Development should continue to refine and improve satellite-derived rainfall estimates. Forecasters should continue to solicit estimates from SFSSs, and SFSSs should continue to advise responsible NWS offices of significant information derived from satellite images.

Finding 3.7

Mechanical problems with the Datalog receiver at WSFO San Antonio interrupted image reception several times.

Recommendation 3.7

NWS should accelerate a plan to replace Datalog receivers with more dependable, trouble-free receivers.

Finding 5.1

Forecast guidance from NMC was not particularly helpful in pinpointing excessive rainfall areas early in the week of July 30. Subjective forecasts improved somewhat by the middle of the week.

Recommendation 5.1

Development of models and techniques to help in forecasting very heavy rains should be continued and given priority for expanded effort.

Finding 5.2

Quantitative Precipitation Branch (QPB) lacked real time rainfall reports from the field. While this did not significantly affect the watches and warnings issued by WSOs/WSFOs, QPB might have provided better guidance had more current rainfall reports been available.

Recommendation 5.2

NWS should institute a Rainfall Report message to relay rainfall amounts above some threshold directly to QPB. The Rainfall Report would be analogous to the Storm Report relayed directly to NSSFC in cases of severe local storms. The report should be a ready-to-use format. This would also help other NWS offices, SFSSs, and RFCs. In addition, QPB should receive in real time all rainfall report relayed via GOES.

Finding 6.1

The San Antonio WSFO staff performed outstandingly in issuing timely, lucid, and effective flash flood watches and warnings. The Hondo radar station put forth a best effort to provide the WSFO with extremely important, pertinent radar information in the face of some technical difficulties with radar frequency stability. The Abilene WSO, with unprecedented requirements for data collection, evaluation, and issuance of flood warnings plus regularly assigned duties, performed in the best of Weather Service traditions over the 3-day episode. The authorized six-person staff was scheduled for maximum utilization of talent though this required many hours of overtime with only short rest periods for some before returning to duty.

Recommendation 6.1

Appropriate commendations should be awarded.

Finding 6.2

The San Antonio office has an outstanding flash flood program.

Recommendation 6.2

The San Antonio flash flood program should be brought to the attention of all appropriate WSFOs. The Flash Flood II Videotape is an effective means.

Finding 6.3

Although it did not affect our services some WSFO forecasters were reluctant to ask for overtime help. This was not a problem at the small WSOs which must use frequent overtime.

Recommendation 6.3

NWS should re-state its policy of using overtime as needed to meet the exigencies of severe weather and flooding situations and that the decision must be made at the local level. At WSFOs the Lead Forecaster, in the absence of the MIC or a PA, must exercise this judgment.

Finding 6.4

Abilene, like most WSOs, is minimally staffed to perform its mission. The staff worked extremely long hours under great pressures to meet service needs of the community.

Recommendation 6.4

Minimum staffing at WSOs should match staffing standards. A minimum staff of 8 is called for at 24-hour WSOs with surface observations, local warning radar, and one NOAA Weather Radio (NWR).

Finding 6.5

Several watches and warnings were adjusted or extended through statements. This is not the most effective way to get attention of the media and public officials.

Recommendation 6.5

The Operations Manual should be brought up to date to include specific instructions on hydrologic service functions and methods, including Flash Flood Watches and Warnings. The methods should be analogous to those for

severe local storms. New Flash Flood Watches and Warnings should be required to extend valid time periods or to include areas not already contained in a current watch or warning area. This procedure would promote full dissemination of the new area or valid time by including the terms "watch" or "warning" in the heading and by including the codes necessary to activate alarms on appropriate teletype circuits. Flash Flood Statements should be used only to remove parts of the areas covered by a watch or warning, to terminate the watch or warning, and to provide pertinent information on current watches and warnings.

Finding 6.6

There were procedural problems relating to watches issued at WSFOs Fort Worth and San Antonio. These problems could be important in some storm situations.

Recommendation 6.6

NWS Southern Region should ensure that office staffs are fully cognizant of proper watch procedures.

Finding 7.1

The broadcast media did an effective job of disseminating flash flood watches, warnings, and statements. Those who listened to TV or radio heard the NWS flash flood advices. We would estimate this includes about 50 percent of the population. Radio was especially effective in repeating weather information. The Kerrville radio station, KERV, and the Kerrville cable TV station both broadcast beyond normal operating hours.

Recommendation 7.1

The media serving the area should be recognized for their exemplary performance during this event.

Finding 7.2

Many Texas Hill Country people received no watch or warning information because they were not listening to radio or watching TV. Others, including some public officials, received information later than they might have. NOAA Weather Radio could have played a substantial role because of its positive alerting feature if the San Antonio broadcast could have reached into the affected areas. It could have delivered watches and warnings more rapidly than by other means. It could have saved lives.

Recommendation 7.2

NWR coverage in the Texas Hill Country should be included in any expansion of the network.

Finding 7.3

While it was not a factor in the dissemination of warnings to the Hill Country, the San Antonio NWR transmitter was knocked off the air by lightning for 2 hours during the storm. Such outages could be critical in future situations as NWR becomes more accepted as a warning medium.

Recommendation 7.3

If practical, standby power and increased lightning protection for all NWR transmitters in high lightning incidence areas should be provided.

Finding 7.4

The National Warning System (NAWAS) was used effectively to disseminate warnings and to solicit feedback from public officials. However, the Kerrville drop was knocked out for nearly 12 hours by flooding.

Recommendation 7.4

NWS should determine, with the Defense Civil Preparedness Agency, how to make NAWAS more fail-safe. If this cannot be done, alternate means for reaching public officials should, if possible, be identified.

Finding 7.5

Expanded use by radio and TV stations of NOAA Public Affairs Office "spots" and press releases on weather emergencies would enhance public preparedness. For a number of reasons, this use is somewhat restricted.

Recommendation 7.5

NWS should review its support to the media and expand it where practicable. NOAA and NWS should also set up procedures for enlisting NWS field offices in promoting NOAA/NWS safety spots with radio and TV stations.

In making this recommendation we recognize that an increase in effort by other State and Federal groups will also produce greater demand for NWS preparedness assistance and support.

Finding 7.6

While the NWS had done considerable amount of outstanding work on community disaster preparedness in the flooded areas, personnel and financial resources available within the field offices are not sufficient to do all that needs to be done.

Recommendation 7.6

The community disaster preparedness effort needs more resources if the job is to be fully accomplished. Either more should be done by other agencies and groups at the Federal and State levels and/or NWS resources should be increased.

Finding 7.7

Many people delayed taking life-saving action because they did not feel sufficiently threatened by our warnings. A probable reason is that they had heard many warnings over the years that were not verified by their own observations.

Recommendation 7.7

NWS must constantly seek ways to make its warnings more specific and meaningful. (See "findings and recommendations" in earlier chapters.) In addition, the NWS should continue to encourage the most vulnerable communities and areas to establish locally operated flash flood warning systems and community preparedness plans. These can make communities more responsive to NWS warnings and can also self-activate the communities when required by localized conditions of which the NWS may not be aware. Flash flood alarms and high community involvement are but two of the most critical ingredients of such systems. (See Chapter 2 for discussion of flash flood alarms and community warning systems.)

Finding 7.8

EBS was not used by the media in the San Antonio area when requested. There was a distinct reluctance to do so.

Recommendation 7.8

Future NWS plans, policies, and procedures relative to the use of EBS should realistically reflect the deep reluctance of many broadcasters to use EBS for weather warnings.

Finding 8.1

The Fort Worth RFC provided outstanding public service during the Texas floods. It is likely that flood forecasts were responsible for saving lives (there were no deaths related to downstream flooding) considering the extent and magnitude of flooding. Timely forecasts allowed people to save property and reduce damage. The small RFC staff of seven hydrologists maintained 24-hour operations from early morning on August 2 until midnight on August 7, and logged 176 hours overtime.

Recommendation 8.1

Appropriate commendations should be awarded.

Finding 8.2

A lack of real time river stage and rainfall data hindered RFC operations. There were no automated gages to interrogate as communications went out and river gages became inaccessible.

Recommendation 8.2

Flood warning programs, like flash flood programs, should be supported by automated gages with satellite and/or radio communications.

# CHAPTER 1

## THE TEXAS FLASH FLOODS

The remnants of Tropical Storm Amelia moved inland over the south Texas coast on Monday, July 31. While heavy rains were expected as it moved across Texas, no one foresaw the extraordinary efficiency with which the atmosphere would dump water in two separate regions over 200 miles apart--the Hill Country northwest of San Antonio and the Big Country area centered over Shackelford County, near Abilene (figure 1.1).

The Hill Country lies just north and west of the Balcones Escarpment, a curving landform that separates the coastal plain from the Edwards Plateau. As a transitional zone from plain to plateau, the Hill Country ranges in elevation from 900 feet to slightly over 2,000 feet above sea level, although local relief doesn't exceed a few hundred feet. It is generally a rolling, thinly populated land of farms, ranches, and small towns. It is also a pleasant picturesque place where people go for recreation and retirement. The countryside is dotted with many summer camps, parks, and vacation homes.

The Hill Country is no stranger to heavy rains and flash floods. Under particular meteorological circumstances, the combination of rising terrain and moist tropical air can easily produce rainfall in excess of 10 inches over a period of a day or so. In 1932, the State Fish Hatchery 15 miles northwest of Kerrville received 35 inches of rain during a 36-hour period. Long-time residents remember the devastation wreaked by the resulting flood. They also recalled devastating floods in 1936 and 1959. Many other large rainfalls and floods have occurred through the years, causing the Hill Country to be recognized as an area very much prone to flash flooding.

Shackelford County, like most of the Big Country which surrounds Abilene, is considerably flatter and drier than the Hill Country. It is mostly an area of wide open spaces devoted to large-scale farming and ranching. The terrain is not particularly hilly. Elevations range from 1,300 feet to 1,900 feet above sea level. Tropical systems infrequently move this deeply into Texas. Consequently, excessive rainfall and flash flooding is less common and usually less severe than in the Hill Country.

Over 30 inches of rain fell in the Hill Country between August 1-3 and in Shackelford County on August 3-4. (See figure 1.2.) These rainfall centers of over 30 inches appear to represent 80-90 percent of the probable maximum precipitation, i.e., the maximum precipitation amount possible from an optimum combination of meteorological factors for these locations. Twelve-hour point rainfall totals of 28 inches in Shackelford County and upwards of 21 inches in the Hill Country far exceeded the respective 100-year return

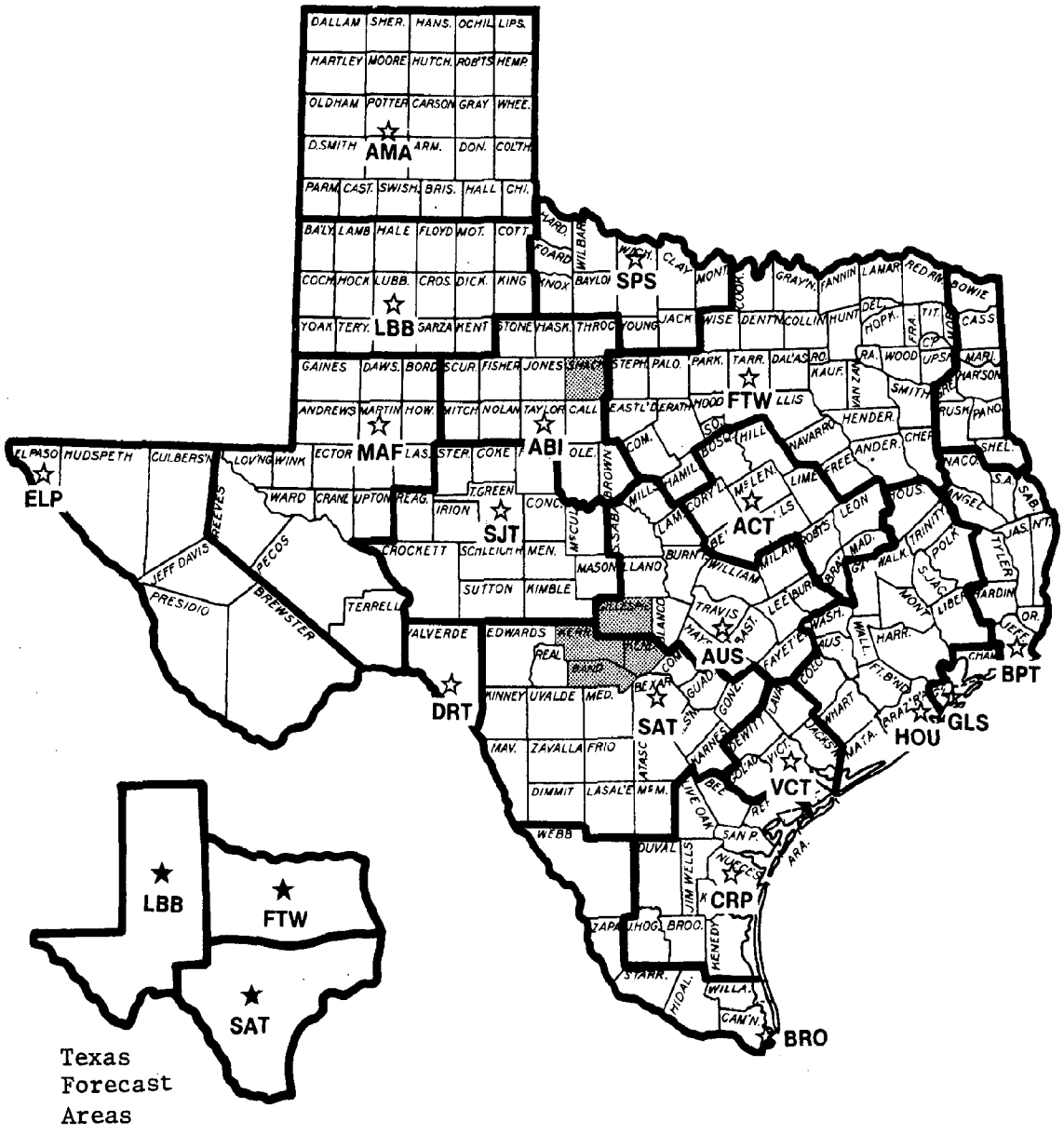


Figure 1.1 -- Texas Forecast and County Warning Areas
(Station Abbreviations Listed in Table 3.1),

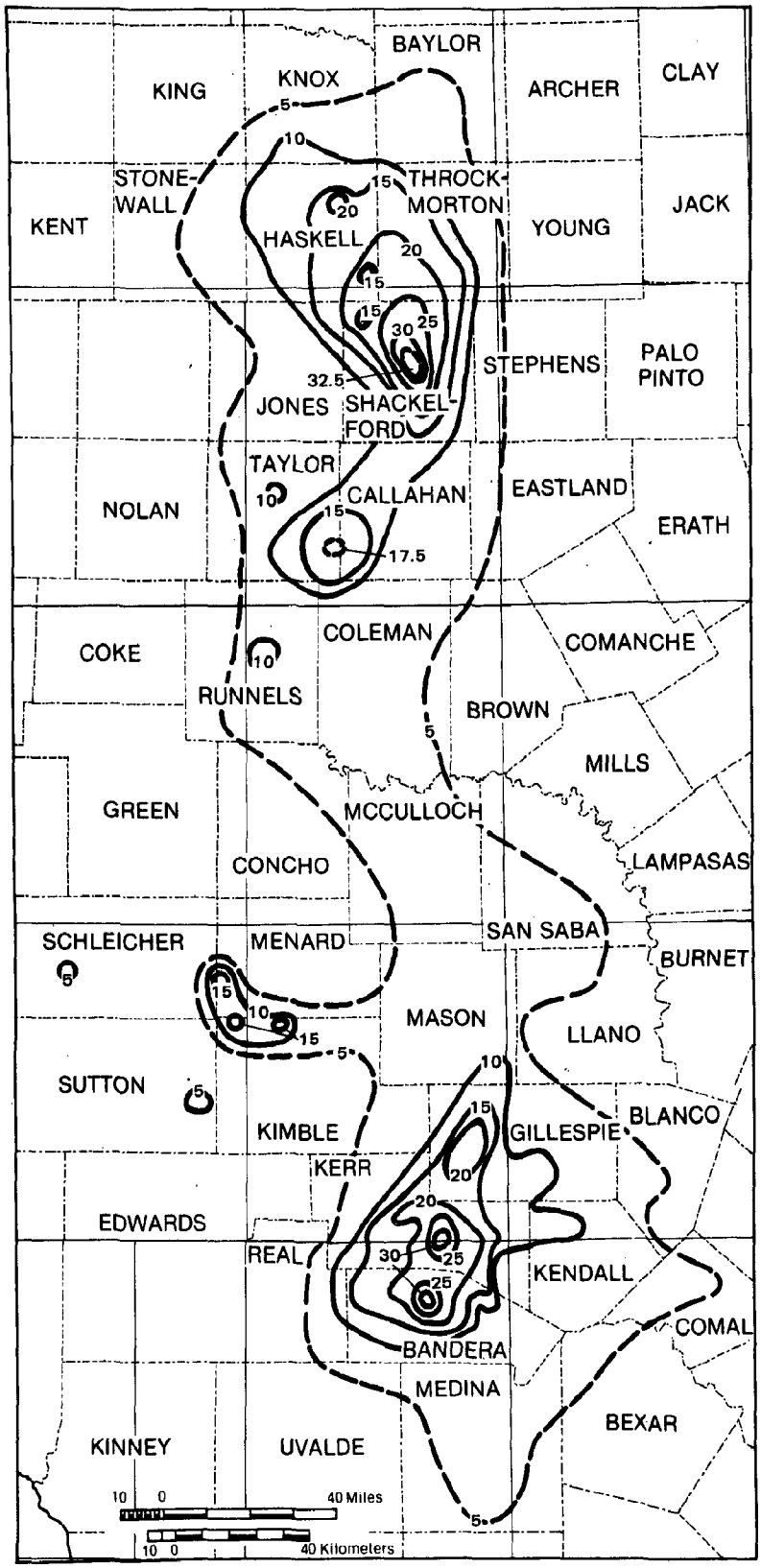


Figure 1.2 -- Isohyetal Map (in inches).

period, 12-hour rainfall values of 7.5 and 8.0 inches for these areas.[1] Hundred-year rainfall amounts for other durations from 1 to 24 hours were also exceeded.[2] Indeed this was an extremely rare event, but just how rare is not possible to say with confidence. The flash flooding produced by this rainfall was understandably of extraordinary magnitude. Alltime record flooding was recorded at several points.

As is so often the case, the killer flash floods occurred during the early morning hours in the Hill Country. Twenty-seven people died there on August 2. (See table 1.1.) Fortunately, the flash floods in the counties near Abilene peaked during the early evening of August 3 when people were up and about. Still, six people died there.

Property damage collectively ran into the tens of millions of dollars. These were heavy losses considering the population density in both areas. The Federal Disaster Assistance Administration estimated that 370 homes were seriously damaged or destroyed in Kerr, Kendall, and Bandera Counties. Hundreds more were damaged or destroyed in Shackelford and other northern counties.

The losses didn't stop here. Cars, trailers, cattle, and all manner of property were destroyed in large numbers. The extent of the destruction was very impressive and quite moving to team members. For example, hundreds and hundreds of large cypress trees, 2 and 3 feet in diameter, were destroyed along the creeks of the Hill Country. Many of these apparently healthy trees were snapped off well above their bases. These fallen works of nature gave mute but very effective testimony to the force of the flash flood waters that had snuffed out so many lives.

Ironically, counties that had just applied for Federal disaster relief because of a prolonged drought were now forced to seek both drought and flood relief at the same time.

The Texas Flash Floods of early August 1978 join an ever-growing series of major flash flooding events that have now statistically become the number one weather-related killer.

The chapters that follow will discuss the various aspects of the disastrous flash flooding in some detail--the operations of the National Oceanic and Atmospheric Administration, the hydrometeorological conditions, the role of the media and public officials, and the response of the public. The last chapter departs from the main subject of the flash flooding and covers main stream flooding which became a significant problem.

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1. Rainfall Frequency Atlas of the U.S., Tech. Paper No. 40, US DOC, Weather Bureau, 1961.
2. A 100-year return period rainfall is a rainfall which statistically would be expected to occur with a frequency of once per 100 years. In reality, such rainfall could occur on consecutive days.

Table 1-1

Information on Casualties

| Hill Country: 27 | Number | Remarks |
|---|---|---|
| Kendall County | | |
| Comfort City . . . . . | 3 | 1 occurred on Highway 27 in a car; 1 died trying to save cattle in pasture; 1 in home (76 years old) |
| Kerr County | | |
| near Centerpoint along Verde Creek . . . . . | 8 | All were in or close to homes or mobile home. All were very young or 60 or over (18 months, 11, 13, 60, 64, 65, 65, 81) |
| Gillespie County | | |
| US Highway #290 at Spring Creek . . . . . | 2 | Both were in cattle truck, washed from road. |
| Bandera County | | |
| Bandera City . . . . . | 2 | All were in or close to homes. Most were either very young (5, 6, 11) or senior citizens (62, 69, 71, 72, 74, 79, 80, and one age unknown but elderly, three others 41, 42, 51) |
| Camp Bandian . . . . . | 8 | |
| Peaceful Valley Branch . . . . . | 4 | |
| **Big Country: 6** | | |
| Shackelford County | | |
| Albany . . . . . | 6 | All deaths are believed to have occurred within the immediate vicinity of Prong Creek. |
| TOTAL . . . . . | 33 | |

# CHAPTER 2

## AN OVERVIEW OF THE FLASH FLOOD WARNING SYSTEM

The NWS has officially conducted an active flash flood warning program since 1971. The primary objective of the flash flood program is to save lives. By definition, flash floods are floods immediately following heavy or excessive rainfall, dam or levee failure, or the sudden release of water impounded by an ice jam. In general, rainfall-induced flash floods come on very suddenly, are difficult to forecast, crest within a few hours, and inundate areas rarely affected by high water. The nationwide flash flood warning system designed to cope with these dangerous situations is composed of the following elements: data acquisition, communications, the issuance of flash flood watches and warnings, dissemination, and community preparedness.

Data acquisition and communication will be discussed in detail in Chapter 3. The issuance of flash flood watches and warnings, including the specific hydrometeorological conditions of Tropical Storm Amelia and the flash flood guidance products available to the San Antonio and Fort Worth WSFOs, are covered in Chapters 4, 5, and 6. Dissemination, community preparedness, and public response are addressed in Chapter 7. Again, Chapter 8 deals with the main stream flooding.

The purpose of this chapter is to provide an overview of how the system works and to provide specific details on the flash flood warning system for the affected areas of Texas.

Apart from perceiving the danger of a flash flood situation, the public can receive flash flood information in three ways: (1) public flash flood watches, warnings, and statements issued by local Weather Service warning offices, (2) community-operated warning systems, and (3) flash flood alarms installed on streams where flash flooding is frequent. These three methods will be discussed separately.

### Flash Flood Watches, Warnings, and Statements

Weather Service Forecast Offices (WSFOs) are responsible for the issuance of flash flood watches for their entire forecast area. Flash flood watches inform the public that developing hydrometeorological conditions could cause flash flooding within a designated watch area and time period. Watches are issued when the threat of flash flooding is possible, but not imminent. Watches are to be issued as far in advance of potential flash flood producing events as meteorologically possible. Consequently, the issuance of a watch normally depends heavily upon guidance from the National Meteorological Center (NMC), the local River Forecast Center (RFC), and an awareness of the development or likely development of a potentially

dangerous situation. The watch message explains what the watch means and gives the geographic area or basin covered by the watch, the effective time of the watch, the reason(s) for the watch, and, when possible, the severity and extent of expected hazardous conditions.

Flash flood warnings are issued by WSFOs and WSOs for their local county warning areas. Warnings are directed toward communities, counties, streams, or other areas where flash flooding is imminent or in progress. They are intended to impress upon the public the serious nature of the situation so to minimize hesitation in taking necessary life protection actions. Typically, flash flood warnings are issued when radar observations, satellite imagery, or rainfall reports indicate that rainfall is or may be sufficient to cause flash flooding. This can be ascertained by comparing reports and observations with Flash Flood Guidance. Flash Flood Guidance is computed daily by the RFC on the basis of antecedent precipitation. It provides an index of soil moisture used to alert warning offices to the average value of rainfall over specified areas which may be sufficient to cause flash flooding. In some instances lacking observed or reported data, a warning may be issued on the basis of upstream flash flooding.

The warning message itself normally contains the effective time period of the warning and the community, county, stream, or other geographic area expected to experience flash flooding. In addition, the message explains what a flash flood warning means and describes the event, the urgency of the situation, and usually lists the actions necessary to protect life and property.

As a followup to flash flood watches and warnings, the issuing office prepares and disseminates flash flood statements to keep the public informed. Statements are also used to terminate all or part of an existing warning or watch.

The preparation and issuance of these flash flood products requires a great deal of coordination and communication between various offices of NOAA, the data network, the media, and local officials. Weather Service personnel must be prepared to deal with flash flood situations at any time. Their experience and judgment is vital to the success of this public service.

Time is a crucial factor in flash flooding. Watches, warnings, and statements must be disseminated to the public as quickly as possible. The flash flood warning system incorporates many communication systems to expedite distribution. Flash flood watches, warnings, and statements are broadcast over the NOAA Weather Radio (NWR) system. They are also transmitted over the NOAA Weather Wire Service (NWWS) that serves most television stations, many commercial broadcast stations, principal newspapers, and many local government offices and weather sensitive private industries. Further broad dissemination to the public is accomplished by the broadcast media. Nearly

all broadcast media not on the Weather Wire receive the information by relay from either United Press International or Associated Press, which in Texas are subscribers to the Weather Wire. Additionally, such information is provided by telephone to key public officials. As this workload could compromise warning and forecast operations, it is handled on a priority basis. Other Weather Service offices receive watches and warnings via Radar Report and Warning Coordination (RAWARC) and/or National Warning System (NAWAS) circuits. The Texas Department of Public Safety is also on RAWARC and NAWAS.

WSFO areas of responsibility and county warning areas for Texas are shown in figure 1.1. WSFO San Antonio (SAT) is responsible for issuing both flash flood watches and warnings for Kerr, Kendall, and Bandera Counties in the Hill Country of south-central Texas. WSO Austin (AUS) issues local warnings for Gillespie County. Flash flood watches for Shackelford County in north-central Texas are the responsibility of WSFO Fort Worth (FTW). Local warnings for Shackelford County are provided by WSO Abilene (ABI).

Community Operated Flash Flood Warning System

Several flood-affected communities in Texas have well-designed local flash flood warning systems. These have been developed in cooperation with individual communities and are designed so that communities can make their own approximations of crest forecasts and initiate flash flood warnings locally, using prepared tables and local rainfall information. Typically, a service hydrologist at the Weather Service Forecast Office identifies the problem area, holds discussions with community leaders on what the Weather Service can provide, and explains the procedures. The RFC assumes the principal technical role in developing the procedures and translating them into a form readily usable by local officials. NWS educates communities in weather-related disaster preparedness and trains local people to operate their own flash flood systems. Local flash flood warning systems typically consist of criteria and procedures for initiating action, a locally operated forecast model, and a warning list. In the Hill Country, the City of Kerrville and Kerr County jointly operate such a local warning system. In neighboring Bandera County, a headwater procedure for the Medina River at Pipe Creek is used to forecast inflow to Medina Lake. NWS efforts to establish a local warning system in Bandera County and the communities of Bandera and Medina have been in progress for some time, but have not yet been realized. In north-central Texas, the communities of Abilene, Brownwood, and Snyder have well-established local flash flood warning systems.

Flash Flood Alarms

Flash flood alarm systems provide an alternative local warning system which can be used independently or as a supplement to a locally operated community warning system. Alarms are extremely valuable when installed on streams

susceptible to flash flooding. Flash flood alarm systems consist of the following elements: a sensor along a river or stream to detect rapidly rising water; a relay station; an alarm located in a staffed alert office; and a complete preparedness plan with lists of persons to be called and other actions to be taken when the alarm sounds. The flash flood sensor is usually installed several miles upstream from a community.

The only flash flood alarm in the flooded areas is located on the Upper Guadalupe River in Kerr County. The flash flood sensor is at Ingram, approximately 7 miles upstream from Kerrville. During the recent floods, the alarm was located at the Kerrville Police Department. However, since the flood, it has been relocated to the Kerrville Fire Department. A rise to the critical level at Ingram causes the alarm to sound. The flash flood alarm system is an integral part of the Kerrville flash flood warning system.

# CHAPTER 3

## DATA ACQUISITION AND COMMUNICATIONS

The collection and transfer of hydrometeorological data are fundamental to all services provided by NWS. Knowledge of current and recent weather conditions are particularly pertinent and necessary for operational forecasting. NWS routinely receives weather and hydrologic data from a variety of real time observing stations, substation networks, and other sources. The continuous collection, transfer, processing, and storage of data requires the use of many communication systems. The major types and sources of data and communication systems available during the Texas Flash Floods will be discussed in this chapter.

### SURFACE DATA

Surface observation networks are the backbone of all operational forecast systems. Surface reporting stations can be separated into two general categories: (1) stations that routinely provide real time synoptic scale data for immediate use; and (2) substations that provide rainfall and/or river stages daily or more frequently when rainfall or stage criteria have been equaled or exceeded.

The location of regular real time reporting stations in Texas is given in figure 3.1. Nearly half are operated by the NWS. The remainder are operated by the FAA and the military. Additional information on each station is given in table 3.1. These stations provide the raw synoptic data necessary for forecasting. In addition to taking and reporting hourly observations, many stations, including all NWS stations, report accumulated 6-hour precipitation totals.

There are 518 official substations in Texas reporting rainfall and/or river information directly to designated WSFOs and WSOs either daily or on a special event basis. Most rainfall reporting substations report via telephone once or several times a day when a reporting criteria (usually 0.50 inches) has been equaled or exceeded during the 24-hour reporting period. Official substations are operated by volunteers under cooperative agreement with the Weather Service. Typically, they perform this service for little or no pay. Figure 3.2 shows Hill Country and Big Country substation locations.

In addition to synoptic and substation networks, WSFOs and WSOs often receive many reports from unofficial rainfall stations. These stations are operated by various government agencies, water authorities, power companies, radio stations, and individuals such as farmers and ranchers. Reports from unofficial stations are generally volunteered or solicited directly over the telephone.

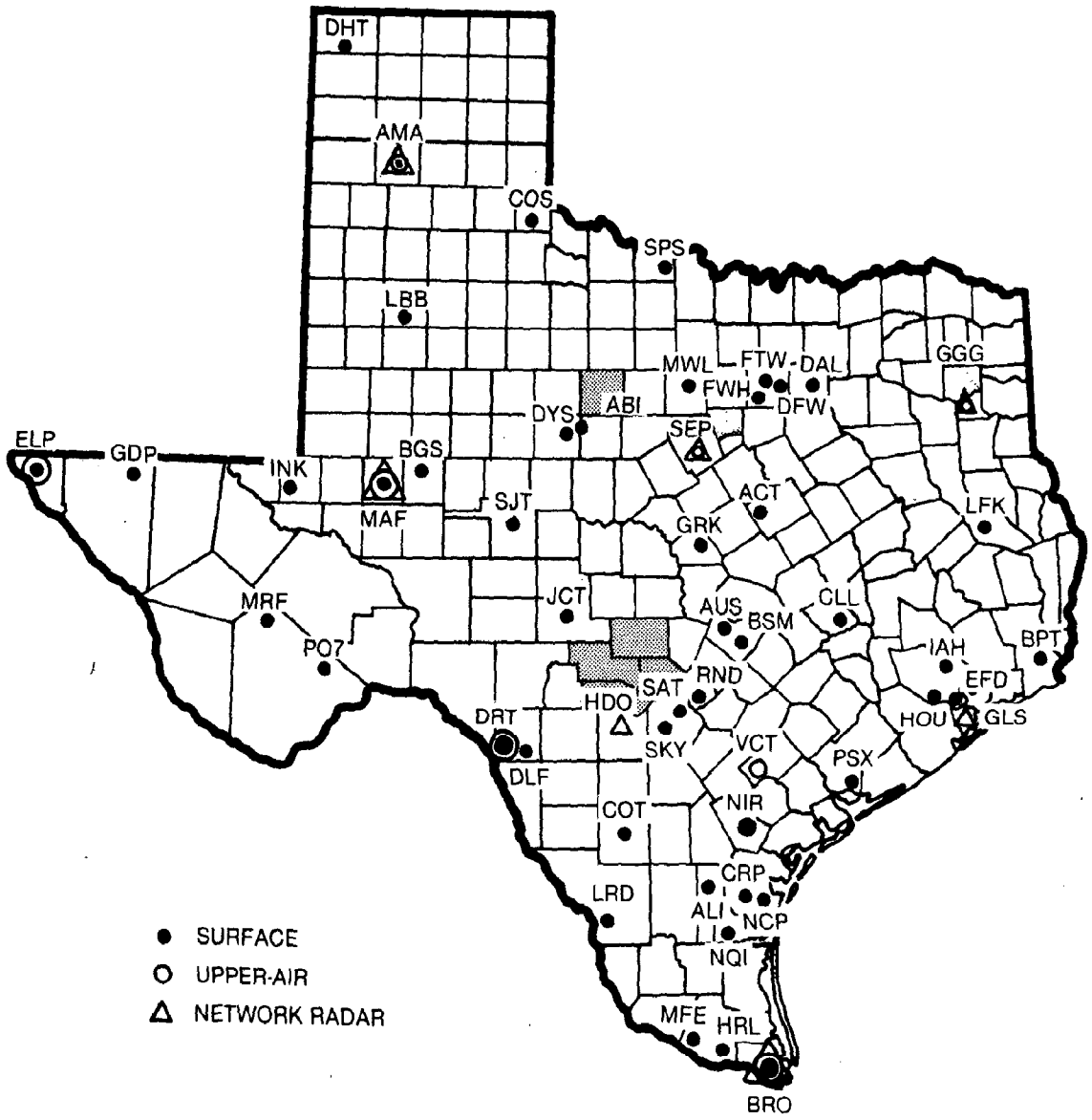
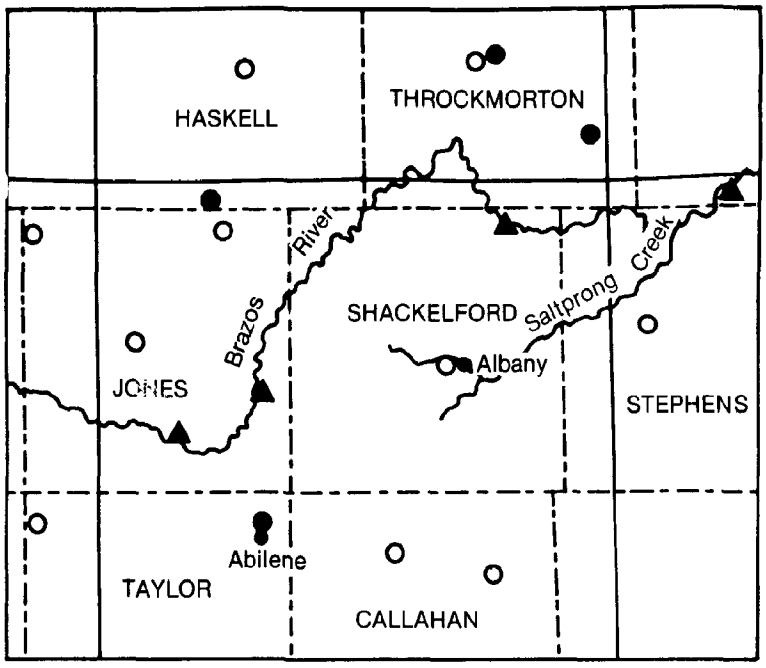


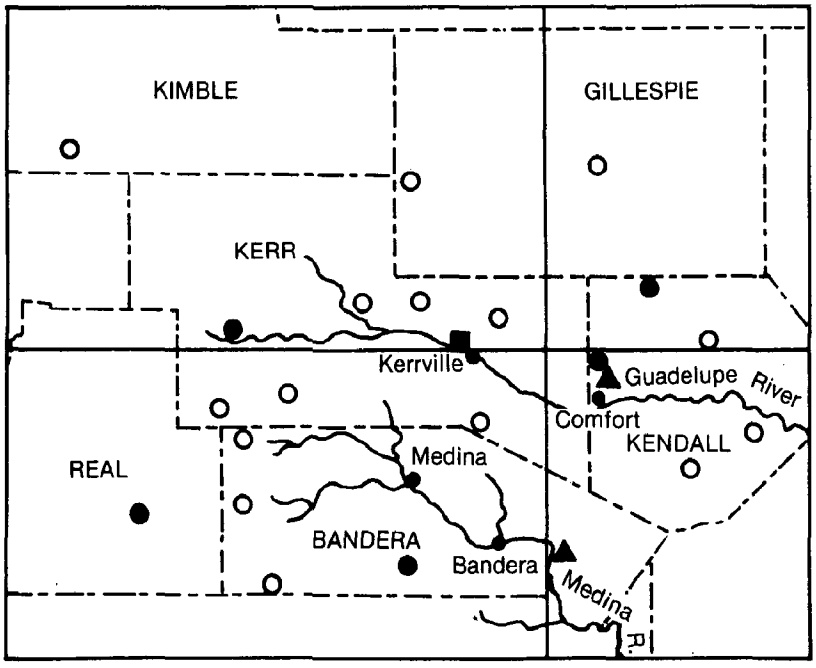

Figure 3.1 -- Texas Regular Real Time Reporting Stations.

# Table 3.1--Regular Real Time Reporting Surface Stations in Texas

| LOCATION | CALL LETTERS | OBSERVATION SCHEDULE | COLLECTION AND TRANSMISSION EVERY HOUR | 6-HR PRECIP. | REMARKS |
|---|---|---|---|---|---|
| Abilene | ABI | 24 hours | Service A | Service A and C | National Weather Service |
| Amarillo | AMA | " | " | " | NWS |
| Austin | AUS | " | " | " | NWS |
| Brownsville | BRO | " | " | " | NWS |
| Corpus Christi | CRP | " | " | " | NWS |
| Dallas/Fort Worth | DFW | " | " | " | NWS |
| Del Rio | DRT | " | " | " | NWS |
| El Paso | ELP | " | " | " | NWS |
| Galveston (AMOS) | GLS | " | " | Service A | NWS |
| Guadalupe Pass (AMOS) | GDF | " | " | " | NWS |
| Houston | IAH | " | " | Service A and C | NWS |
| Junction (AMOS) | JCT | " | " | Service A | NWS |
| Lubbock | LBB | " | " | " | NWS |
| Marfa (AMOS) | MRF | " | " | Service A | NWS |
| Midland | MAF | " | " | Service A and C | NWS |
| Port Arthur | BPT | " | " | Service A | NWS |
| San Angelo | SJT | " | " | Service A and C | NWS |
| San Antonio | SAT | " | " | " | NWS |
| Sanderson (AMOS) | P07 | " | " | Service A | NWS |
| Victoria | VCT | " | " | " | NWS |
| Waco | ACT | " | " | " | NWS |
| Wichita Falls | SPS | " | " | " | NWS |
| Alice | ALI | 24 hours | Service A | Service A | FAA |
| Childress | CDS | " | " | " | FAA |
| College Station | CLL | " | " | " | FAA |
| Cotulla | COT | " | " | " | FAA |
| Dalhart | DHT | " | " | " | FAA |
| Dallas | DAL | " | " | " | FAA |
| Fort Worth | FTW | " | " | " | FAA |
| Harlingen | HRL | 17 hours | " | " | FAA |
| Houston | HOU | " | " | " | FAA |
| Laredo | LRD | 17 hours | " | " | FAA |
| Lufkin | LFK | 24 hours | " | " | FAA |
| McAllen | MFE | " | " | " | FAA |
| Mineral Wells | MWL | 17 hours | " | " | FAA |
| Palacious | PSX | 24 hours | " | " | FAA |
| Wink | INK | " | " | " | FAA |
| Bergstrom AFB, Austin | BSM | 24 hours | Service A | Service A | Military |
| Carswell AFB, Fort Worth | FWH | " | " | " | " |
| Chase NAS, Beeville | NIR | " | " | " | " |
| Corpus Christi NAS | NGP | " | " | " | " |
| Dyess AFB, Abilene | DYS | " | " | " | " |
| Ellington AFB, Houston | EFD | " | " | " | " |
| Gray AAF, Kileen | GRK | " | " | " | " |
| Kelley AFB, San Antonio | SKF | " | " | " | " |
| Kingsville NAS | NQI | " | " | " | " |
| Laughlin AFB, Del Rio | DLF | " | " | " | " |
| Randolph AFB, San Antonio | RND | " | " | " | " |
| Webb AFB, Big Spring | BGS | " | " | " | " |




BIG COUNTRY SUBSTATIONS




HILL COUNTRY SUBSTATIONS

O STANDARD RAIN GAGE
▲ RIVER FORECAST POINT
● RECORDING RAIN GAGE
■ FLASH FLOOD ALARM

0 25 50 MILES

Figure 3.2 -- Hill Country and Big Country Substations.

It is well known that areas of Texas like the Hill Country are rather frequently deluged with excessive rainfall, and that flash flooding is a recurring problem in these areas. During this event, rainfall of 10 to 30 inches occurred over widespread areas of Texas including the Hill Country. However, few real time observations of heavy rainfall were available to NWS offices. In part this was due to telephone outages in the Hill Country, beginning at 5:45 a.m. on August 2. However, communication problems only tend to compound an existing data acquisition problem. When heavy flash flood producing rains occur at night, as is often the case, volunteer reporting networks do not always report as quickly as is necessary to adequately support flash flood warning systems. The magnitude and extent of heavy rainfall in both the Hill Country and Big Country was not fully reported and realized until after the fact.

The regular reporting synoptic network is not particularly dense in Texas. (See figure 3.1.) None of these stations received heavy rainfall. There are 30 automated rain gages in Texas that supplement the full-time synoptic network. Most of these automated gages can be interrogated directly by WSFOs and WSOs via telephone. However, no automated gage lies within the large areas that received more than 10 inches of rainfall.

The network of substations is rather evenly distributed and dense in the flash flood areas. (See figure 3.2.) However, reports from these stations were neither frequent nor timely enough to indicate the real time occurrence of heavy rainfall. Two main factors weaken the contribution of substations. First, observers are not always physically close to their gages--they may be working, sleeping, etc. Second, telephone lines by which they report can easily fail during a flood, as in this situation. Although substation network stations provide a much needed service, they are not stations that can be monitored or interrogated 24 hours a day. Reports from substations and unofficial stations, while potentially very valuable, cannot be depended upon as the only source when time is critical to a forecast operation. Automated gages are needed to fill large gaps in the regular reporting network, especially in areas prone to flash flooding.

RADAR DATA

Continuous network weather radar coverage for Kerr, Bandera, and Kendall Counties in the Texas Hill Country is provided by the Weather Service WSR-57 10-cm wavelength network radar at Hondo, about 40 miles west of WSFO San Antonio. Coverage for Shackelford and adjacent counties, including the Albany area, is provided by the WSR-57 10-cm wavelength network radar at Stephenville, about 80 miles east of WSO Abilene. Both the Hondo and Stephenville radars are staffed for continuous radar surveillance.

The two network radars are backed up by various NWS local warning and military radars. Additional radar coverage of the Hill Country is provided by local warning radars at:

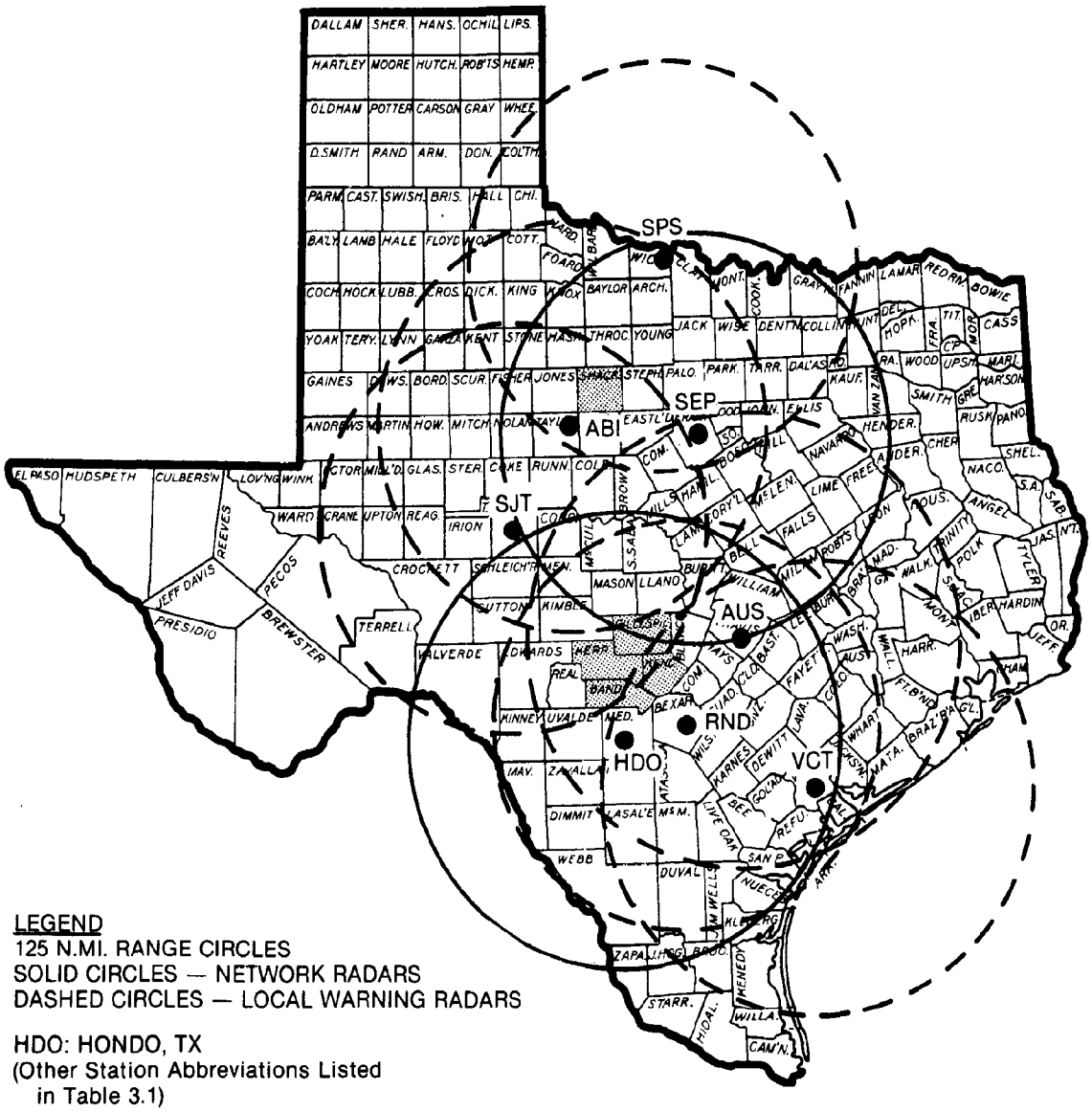



Figure 3.3 -- Hill Country and Big Country Radar Coverage.

| | Wavelength |
|---|---|
| WSO Austin | 5 cm. |
| WSO San Angelo | 5 cm. |
| WSO Victoria | 10 cm. |
| Randolph AFB | 5 cm. |

Additional coverage of the Albany area is provided by local warning radars at:

| | |
|---|---|
| WSO Abilene | 5 cm. |
| WSO Wichita Falls | 5 cm. |

NWS local warning radars are operated whenever weather echoes are detected or are expected to develop within 125 nautical miles of the radar. They are operated by WSO personnel involved in many different activities while on duty. In other words, local warning radar observations are but one of several essential duties.

Information Provided

Routine duties at the network radar stations include making hourly radar observations that are encoded and transmitted on the RAWARC circuit, preparing hourly radar summaries (narrative descriptions of the observed precipitation patterns and intensities) that are disseminated on NOAA Weather Wire and often recorded on nearby NOAA Weather Radio stations, and preparing hourly tracings of the radar scope on paper overlays which depict the surrounding geography and jurisdictions. When specific criteria are met, the radar operator also takes and disseminates intermediate special observations. Both network (WSR-57) radars have Radar Remote (WBRR) transmitters to provide echo displays on facsimile recorders at other offices. Hondo has a dedicated line to WSFO San Antonio; Stephenville has one to WSFO Fort Worth. The receivers at these forecast offices can be pre-set to receive an image continuously or at 5-, 10-, 20-, or 60-minute intervals.

In addition to the hourly duties listed above, the radar operator is required to annotate the WBRR display by hand at least once every hour using a Data Insertion Device (DID). These annotations include coded descriptions of the echoes in terms of precipitation type, areal coverage, intensity, intensity trend, speed and direction of movement, and location and height of maximum echo tops. Echo configuration (lines and areas) is also noted. The display usually includes range marks and some geographic and other significant features. However, NWS offices with WBRR receivers are also supplied plastic overlays depicting locations of towns and often rivers, counties, highways, etc. These plastic overlays can be used to check echo movement or persistence by marking significant echo locations with each successive WBRR image. However, the effectiveness

of this procedure is sometimes reduced by poor intensity resolution on the WBRR image.

Both the Hondo and Stephenville radars, as well as the local warning radars at WSOs Abilene, Austin, San Angelo, and Wichita Falls, are equipped with Video Integrator and Processor (VIP) units that automatically contour up to six intensity or reflectivity levels. These levels can be used to make coarse rainfall rate estimates. Such estimates, as well as measurements of echo tops, are limited to the area within 125 n.mi. from the radar antenna because of decreases in measurement resolution beyond that range. VIP levels are included in the coded radar observation (SD) by encoding the maximum of the six VIP levels observed in each of 100 or so squares forming a grid over the 125 n.mi. range. Each square is about 22 miles on a side. This procedure replaced the old manually digitized radar (MDR) scheme in early 1978. The current grid boxes are one-fourth the size of the MDR boxes, resulting in much better resolution. However, the large volume of the data is more difficult for forecasters to assimilate.

The following table shows the VIP intensity code numbers, corresponding echo intensities, and estimated rainfall rates.

| Code Number (VIP Level) | Echo Intensity | Estimated Rainfall Rate (in/h) | |
|---|---|---|---|
| | | Stratiform | Convective |
| 1 | Light | Less than 0.1 | Less than 0.2 |
| 2 | Moderate | 0.1 - 0.5 | 0.2 - 1.1 |
| 3 | Heavy | 0.5 - 1.0 | 1.1 - 2.2 |
| 4 | Very Heavy | | 2.2 - 4.5 |
| 5 | Intense | | 4.5 - 7.1 |
| 6 | Extreme | | More than 7.1 |

Using estimated rainfall rates associated with the VIP levels, a forecaster can manually estimate rainfall over a particular area and time period. While a great improvement over spot echo intensity measurements made without the benefit of the VIP, the procedure requires time and effort on the part of the forecaster. RADAP (RAdar DAta Processor) will automate this process and provide data with still higher resolution.

The air mass which brought the flash floods to the area was very moist. Individual rain cells operated at maximum efficiency. The rains, of the convective type, were quite variable in space and time. The VIP values reported once per hour in the MDR code imply ranges of rates and accumulations which are consistent with observed rainfall amounts, but do not provide definitive point estimates.

Hondo Radar Support to WSFO San Antonio

The staff at WSMO Hondo provided excellent support to WSFO San Antonio during the two nights of heavy rain in the Texas Hill Country, despite limitations caused by failure of the automatic frequency control (AFC) and the lack of experience with a new VIP unit. The VIP was installed on June 5, 1978. Few precipitation events occurred between the time of installation and the onset of the flood producing rains. There was therefore not sufficient opportunity for operators to become familiar with the system under operational conditions to assure optimum performance. The radar automatic frequency control experienced frequency drift on both nights of heavy rainfall. However, the radar operators were able to establish proper frequency by manual methods prior to recording observations with the result that the quality of observations was not affected significantly. The frequency drift did, however, have an adverse effect on the radar representations received on the WBRR remote receiver at San Antonio to the extent that the intensity levels shown at times other than when the frequency was under control would have been degraded. This was compensated for in part by frequent readjustment of the receiver. Because of the AFC difficulty, the Hondo radar station annotated their Data Insertion Device (DID) transmissions with the term ROBEPS (Radar Operating Below Performance Standards).

Radar summaries were very well written. Most contained specific information on the location of the heaviest storm cells and estimates of rainfall rates. Most summaries during the early morning hours of August 2 and 3 began with remarks about heavy thunderstorms continuing in the Hill Country. The persistence of the echoes was quite significant. It meant heavy rain was continuing over the same area. The radar operators maintained clear DID annotations for the WBRR display.

The WBRR display at WSFO San Antonio was only marginally useful in locating the strongest echoes on the Hondo radar and in maintaining a watch of intensity trends and echo movement. There was very poor resolution of intensity levels beyond VIP level 2. This was a constant problem and not likely a sole result of the AFC fluctuations. Plastic overlays were apparently not used by forecasters to watch for persistence of particularly strong cells over the flood area. However, the poor intensity resolutions would have limited the usefulness of such efforts. The forecasters relied heavily on telephone contact with the radar operator and on the coded radar observations (SDs) for more detailed information on intensities, trends, and movements.

Few attempts were made to maintain running totals of VIP levels for grid boxes. Several staff members of the San Antonio and Hondo offices stated that the change to a finer grid and new VIP level scheme had made the

totalling of hourly VIP levels much more time consuming. It is reasonable to conclude that with the press of many duties in this extraordinary situation the forecasters simply were not able to use this tool to best advantage.

Rainfall estimates were based on VIP levels. The lead forecaster on duty during the early morning hours of August 2 estimated rainfall rates of 1 to 2 inches per hour (VIP 3), with a maximum of 5 inches in 3 hours, with up to 10 inches in 5 hours, from VIP levels over the flood area. These appear to be reasonable estimates considering the state of the art in radar measurements. One rain gage 4 1/2 miles northwest of Medina caught over 13 inches in the 5 hours between 2 a.m. and 7 a.m. on August 2--an average of 2.6 inches per hour. A review of the Hondo radar film revealed similar correspondence between rainfall estimates using VIP levels and observed rainfall.

Stephenville and Abilene Radar Support to WSO Abilene

The Stephenville radar, with a worse than average performance record, suffered intermittent radiation dropout for a 2-week period prior to the storm event. The radar was removed from service for necessary repairs at 12:37 p.m., August 3, and was restored to normal service on Saturday, August 5.

The small staff at WSO Abilene, augmented by two observers detailed from Stephenville, fulfilled its responsibility as backup to the Stephenville radar. Stephenville's personnel covered Abilene radar shifts from 4 p.m., Friday, until 8 a.m., Saturday, and again from 4 p.m. until midnight, allowing the Abilene staff to rest and get caught up with other flood-related duties. The Abilene OIC was quite pleased with and appreciative of staff performances.

Meanwhile, the Stephenville office continued to transmit hourly radar summaries on NOAA Weather Wire during the entire outage as required by the NWS Weather Radar Manual. The summaries were based on data from nearby radars and surface reports.

In general the Abilene radar did a good job of depicting the centers of heavy rains over its warning area. As characteristic of short wave-length radars, however, attenuation was probably significant and almost certainly caused some underestimation of areal coverage of heaviest rainfall. Localized heavy rain near Albany produced approximately 28 inches in the 12-hour period beginning at 6 p.m. on August 3. This is an average of about 2 1/3 inches per hour for 12 hours and equates to VIP level 4 for 12 hours. Between 6:30 p.m., August 3, and 12:35 p.m., August 4, the reported MDR values were consistently VIP 3 or 4 in the Albany square.

VIP levels 2 and 3 characterized the afternoon observations on the 3rd and considering the extent of the flooding by 8 or 9 p.m. that night, almost assuredly the rainfall rate probably exceeded that estimated by radar. VIP 4 echoes (estimating rainfall up to 4.5 inches per hour) were reported at 7:30 p.m. and 8:30 p.m. At this time the flood had already struck Albany.

SATELLITE DATA

NOAA operates an environmental satellite system through its National Environmental Satellite Service (NESS). Two types of satellites are operated by NESS: the polar orbiting spacecraft and the series of spacecraft in Earth synchronous orbit. The latter, known as the Geostationary Operational Environmental Satellite (GOES), is constantly looking at the Earth's cloud patterns from 22,500 miles in space.

WSFO San Antonio and WSFO Fort Worth are equipped with Datalog units to receive images via the GOES Central Data Distribution System every half hour. The routine program consists of both visible and enhanced equivalent infrared (EQIR) images of approximately 1 and 2 km resolution, respectively. The visible and EQIR images alternate during the daylight hours, with only the EQIR at night. Both offices have the option of requesting one km resolution visible images during daylight hours. The advantage of the EQIR representation is that basic infrared data are enhanced or contoured according to one of many relationships between temperatures sensed by the satellite's radiometer and shades of white and gray. The enhanced display of the infrared data allows easy detection of the very cold cloud tops, indicating strong convection and possibly heavy rain. In addition, researchers have devised procedures for estimating rainfall amounts from a series of these enhanced infrared (or EQIR) images.

NESS also operates a series of Satellite Field Services Stations (SFSS) to assist NWS field offices and others in the use of satellite data. The SFSS at Kansas City provides support to 23 WSFOs in the central third of the United States, including those at San Antonio and Fort Worth. In addition to hard-copy images available every half hour, the SFSS meteorologist also maintains a loop of consecutive images in an Image Analyzer that can be viewed on TV monitors. The meteorologist on duty uses the hard copies and movie loops to prepare Satellite Interpretation Messages (SIMs) every 6 hours. They are sent via teletypewriter to WSFOs for guidance. Further telephone coordination is encouraged between WSFOs and the SFSS. The SFSS meteorologist can also request Quantitative Precipitation Estimates (QPEs) using the Scofield-Oliver technique from the Satellite Analysis Branch at the National Meteorological Center (NMC) in Washington, D.C., for relay to WSFOs.

The Datalog units at San Antonio and Fort Worth were operational during the heavy rainfall and flooding, but sporadic paper jams interrupted reception at San Antonio during the critical period from 10 p.m. CDT on August 1 to 1 a.m. CDT on August 2 and again at various times the night of August 2 and early morning of August 3. In one case, for example, the technique indicated a storm total of 15 inches over an area where 30 inches was observed.

Otherwise the satellite images received at WSFOs San Antonio and Fort Worth during the heavy rain and flood episodes of August 1-4 were of good quality and computer-produced grids were generally accurate. Once Tropical Storm Amelia moved inland, satellite images were very useful in following the progress of the low level moisture. They provided an early indication on August 1 that the moisture was advancing into central Texas, west of the position favored for heavy rain by most other guidance.

Every Satellite Interpretation Message (SIM) issued by the Kansas City SFSS from Monday evening, July 31, through Friday, August 4, contained information on the situation in Texas. Most of the attention was given to the location and movement of the upper level vorticity center or wind shear zone, but several SIMs mentioned the progress and position of the low level moisture while others contained descriptions of the significant convection. From the evening of August 1 to the early morning of August 3, there were 10 telephone consultations held between a San Antonio forecaster and the duty meteorologist at the SFSS to discuss satellite data interpretations; eight were initiated by the SFSS. The SFSS also initiated consultation calls to WSFO Fort Worth shortly after midnight on August 3 concerning rainfall indications northwest of Brownwood, and again around 11 p.m. the following evening to discuss a nearly stationary cell in the vicinity of Albany. The August 4, 0100 GMT SIM discussion indicated an upper Low and vorticity maximum 30 miles northwest of Abilene. The associated convection, as shown in the satellite imagery, was most active between Abilene and Fort Worth, southwestward to near San Angelo and the Texas Big Bend. Surface reports indicated rains were continuing in the area northwest of Abilene, including Stamford. However, the flash flood had already occurred, having struck Albany at about 7 p.m. The western edge of the heavy rain accumulations was at about the 100th Meridian, which is the eastern boundary of WSFO Lubbock's forecast district. Between the morning of August 2 and the late evening of August 3 that office had four telephone consultations with the SFSS at Kansas City.

The satellite images, used in conjunction with radar data, were quite helpful in locating the areas of strongest convection and in monitoring convection trends and persistence. However, quantitative precipitation estimates (QPEs) using the Scofield-Oliver technique, while yielding significantly heavy rainfall estimates and helping to fill data gaps, were low compared to rainfall observations.

## UPPER AIR DATA

The NWS operates a national network of upper air stations. These stations provide reports on the vertical distribution of pressure, temperature, water vapor, and wind in the atmosphere. Observations, taken at 0000 and 1200 GMT, provide the basic information used in numerical or computerized weather prediction operations at the National Meteorological Center, Washington, D.C. These reports are also used by the WSFOs directly in forecast operations. Upper air reports are transmitted to NWS forecast and warning offices and to NMC over teletypewriter systems.

Upper air stations in Texas are located at El Paso, Del Rio, Midland, Amarillo, Stephenville, Victoria, Brownsville, and Longview. Nearby stations are at Albuquerque, N. Mex., Oklahoma City, Okla.; Lake Charles, La.; and at Chihuahua and Monterrey in Mexico. Although some upper air data were late or missing at NMC, there is no indication that NMC products were seriously affected.

## FINDINGS AND RECOMMENDATIONS

### Finding 3.1

There were not enough real time river and rainfall reports available to NWS during and after critical river crests, because of (1) the lack of automatic stations and (2) breakdowns in landline communications.

### Recommendation 3.1

Much more effort should be directed toward automation of the river and rainfall reporting networks through AHOS/S and similar automated systems. Existing official rainfall networks should be supplemented with volunteer, unofficial stations using existing storm spotter networks, such as presently operated by amateur radio operators and other cooperators.

### Finding 3.2

Radar data, while not providing precise rainfall measurements, were invaluable to the NWS in its warning efforts. NWS employees, particularly those at Hondo and Abilene, performed outstandingly under difficult circumstances.

### Recommendation 3.2

Every effort should be made to provide field forecasters with even better radar estimates of rainfall rates. (Note: The RADAP program funded by the Congress in FY 79 is expected to make a major contribution in this regard.)

Finding 3.3

There was some loss in the quality of the radar data available to San Antonio via the WBRR radar remote readout because of frequency instability in the basic radar set at Hondo.

Recommendation 3.3

National Weather Service should make every effort to collocate radars and NWS offices with warning responsibility. Efforts should be made to obtain improved remote radar displays where collocating is not possible and to accelerate the implementation of RADAP.

Finding 3.4

Radar summaries are widely read by the media and are an additional way of advising them (and the public) of the status of watches. While there is no firm requirement to do so, some radar summaries headlined the existence of a flash flood watch. However, most did not.

Recommendation 3.4

National Weather Service should consider the desirability of requiring that current flash flood (or severe storm) watches be headlined in radar summaries when watches include part of the 125-nautical mile surveillance area.

Finding 3.5

The Stephenville radar failed during the critical period. It had had a history of relatively poor performance.

Recommendation 3.5

NWS should investigate and correct Stephenville radar downtime problems.

Finding 3.6

Geostationary Operational Environmental Satellite (GOES) data and the Kansas City SFSS played a very useful role in helping forecasters to understand the nature of the weather system causing the heavy rains. However, the satellite-derived rainfall estimates in this particular meteorological situation involving abundant moisture and generally low cloud tops, while showing heavy rainfalls, were generally too low. Nevertheless, they did correlate with the heavy rain areas. In the case of the Albany flooding, the 0100 GMT August 4 Satellite Interpretation Message (SIM) discussed active convection in the general area, but the satellite data did not indicate flood producing rains until several hours after the first flooding struck Albany.

Recommendation 3.6

Development should continue to refine and improve satellite-derived rainfall estimates. Forecasters should continue to solicit estimates from SSFSs, and SFSSs should continue to advise responsible NWS offices of significant information derived from satellite images.

Finding 3.7

Mechanical problems with the Datalog receiver at WSFO San Antonio interrupted image reception several times.

Recommendation 3.7

NWS should accelerate a plan to replace Datalog receivers with more dependable, trouble-free receivers.

# CHAPTER 4

## HYDROMETEOROLOGICAL CONDITIONS

Tropical Storm Amelia developed rapidly over the Western Gulf of Mexico on Sunday, July 30, 1978. The first Tropical Storm Advisory was issued by the National Hurricane Center (NHC) in Miami at 5 p.m. CDT on July 30, stating that the storm center was expected to move inland between Corpus Christi and Brownsville early Monday, July 31.

Amelia moved inland Sunday evening, reaching a point 40 miles north of Brownsville by the time of the second advisory at 11 p.m. CDT. Movement was north-northwestward at 10 mph, but Advisory Number 3, issued at 5 a.m. CDT Monday, headlined Amelia's turn northward. By 8 a.m. CDT on Monday, the storm center was 50 miles southwest of Victoria, moving northward at 12 mph. Heaviest rainfall was along the south coast and up to 190 miles offshore. (See figures 4.1 and 4.2.)

The last advisory on Amelia issued by Miami at 11 a.m. CDT on Monday stated that the poorly defined center was estimated to be 50 miles west of Victoria, moving northward at 12 mph. No change in speed or direction was expected for the rest of the day. Heaviest rainfall remained from extreme southern Texas, northeastward along and just off the coast, but heavy rain began moving northward toward the San Antonio area early Monday night. (See figure 4.3.)

By early Tuesday morning, August 1, there was no longer any sign of a surface Low in southern Texas, but a very sharp gradient of low level moisture with a surface flow favorable for continued moisture transport remained (figure 4.4). The 500-mb vorticity center depicted near the tropical storm location on earlier Limited Fine Mesh (LFM) analyses was no longer discernible by 1200 GMT Tuesday. However, an upper Low and vorticity center were analyzed just west of Monclova, Mexico, about 250 miles south-southwest of Del Rio, Texas. Early morning SIMs from the Kansas City SFSS mentioned an upper level cyclonic shear zone and vorticity center over west Texas, near Midland. Although Amelia had disappeared, the storm's effective moisture transport was evident. Nearly 2 inches of precipitable water was calculated for the 1000- to 500-mb layer at the South Texas Coast from the 1200 GMT upper air data, with over one and a half inches farther inland through central Texas.

Early morning rainfall reports on Tuesday revealed totals of 4 to 5 inches overnight from the eastern part of the Texas Hill Country through the San Antonio area. Kerrville had 4 inches overnight.

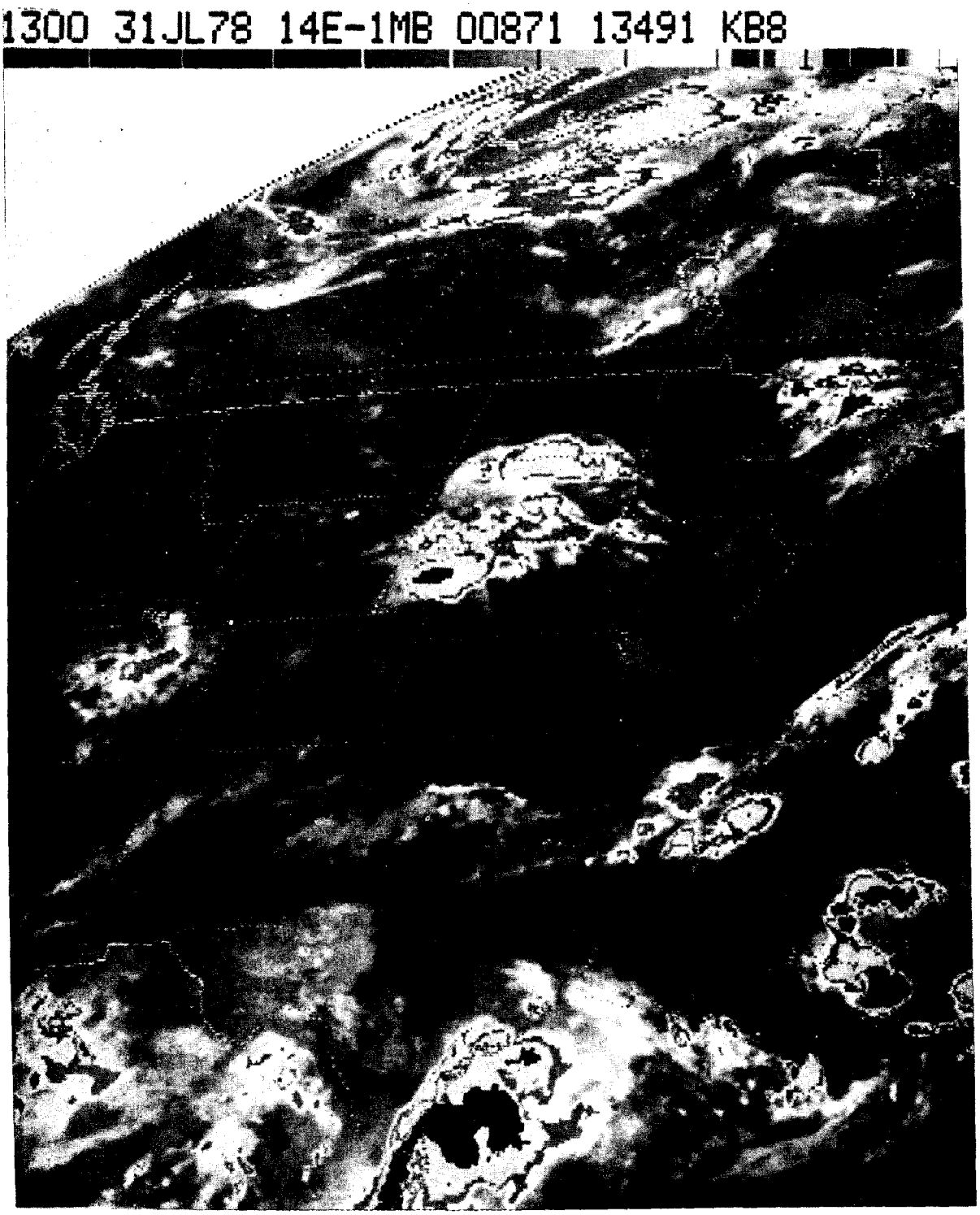



Figure 4.1 -- July 31-1300 GMT EQIR Equivalent Infrared Satellite Image.

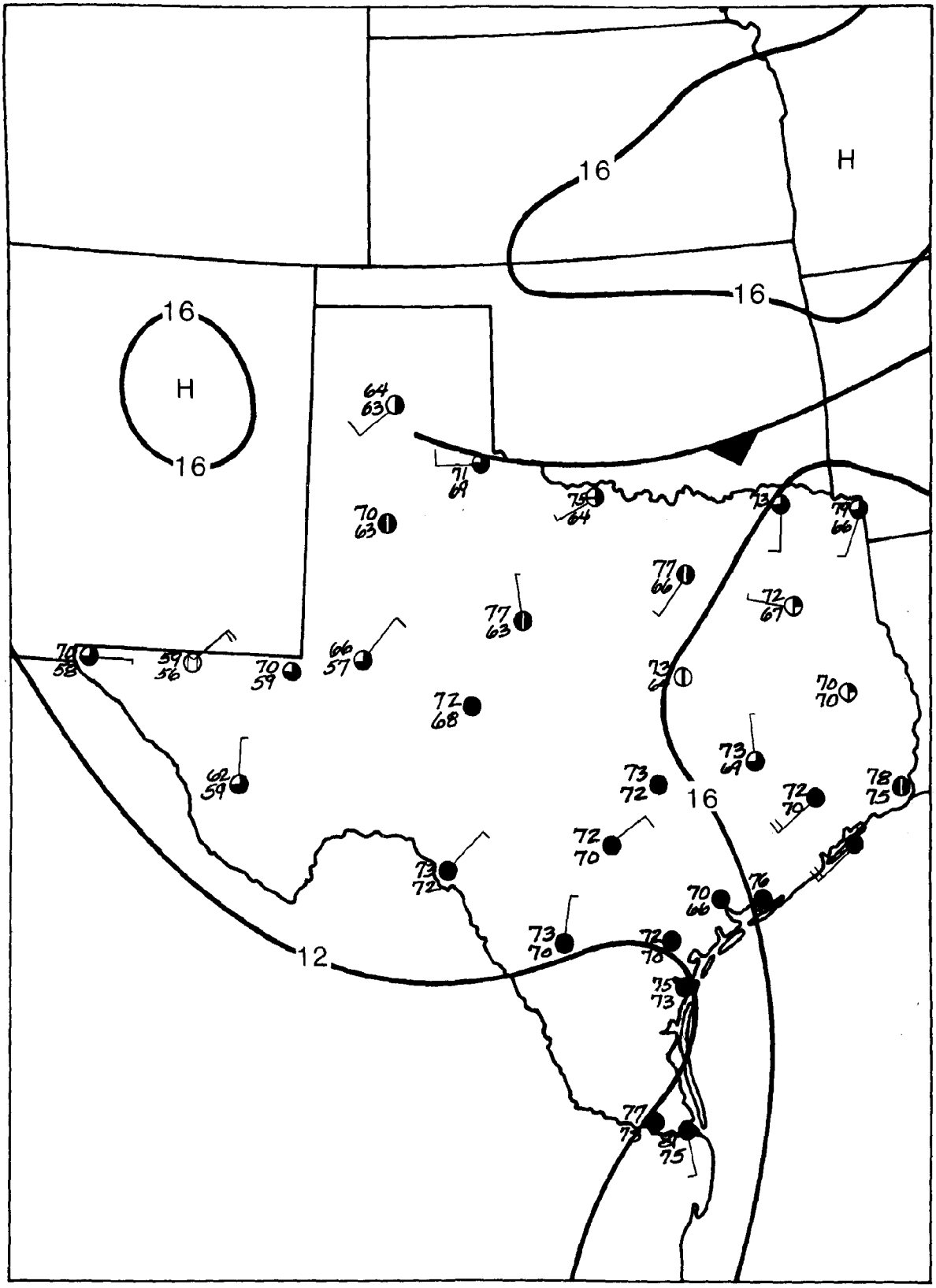



Figure 4.2 -- July 31--1200 GMT Surface Analysis.

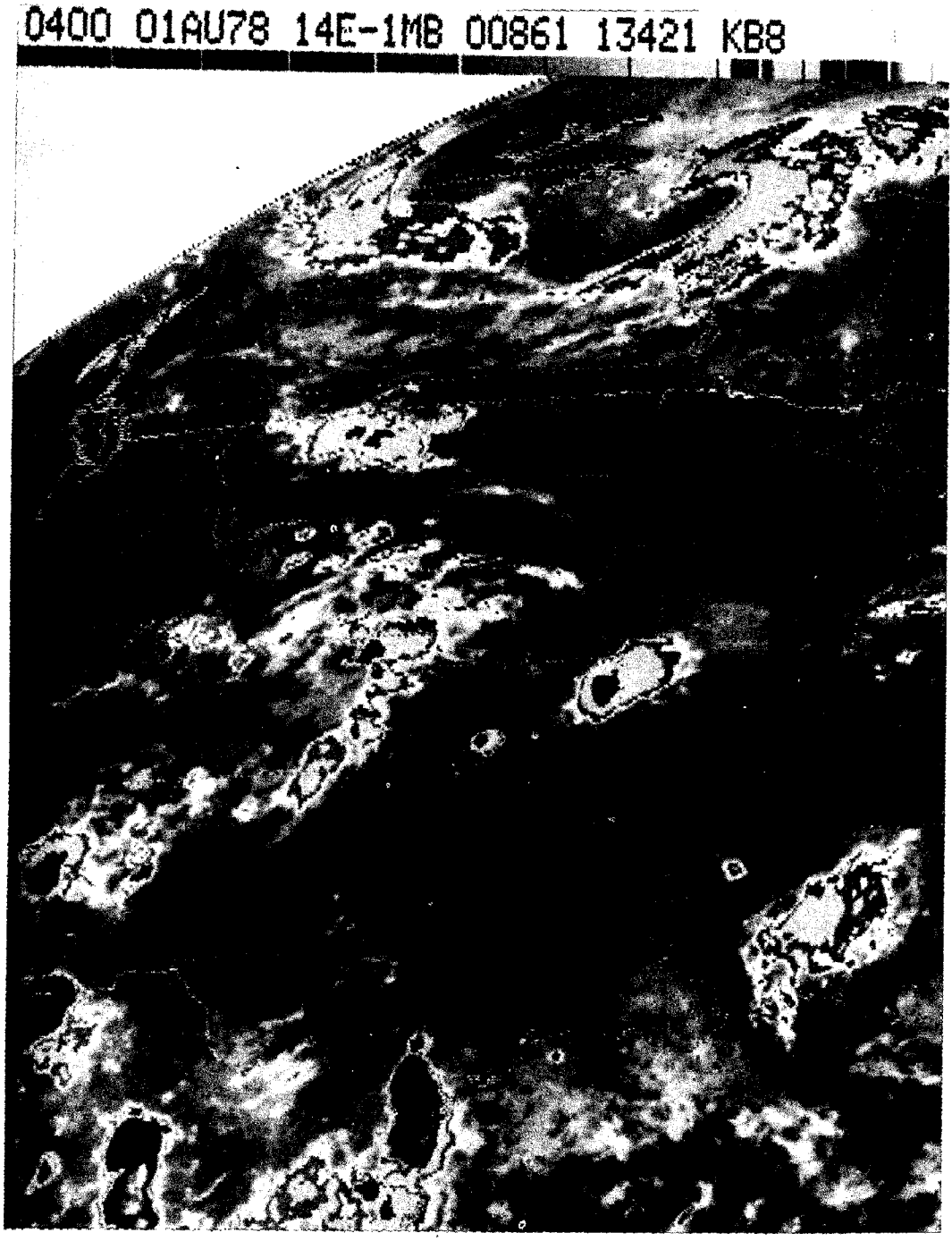



Figure 4.3 -- August 01-0400 GMT EQIK.

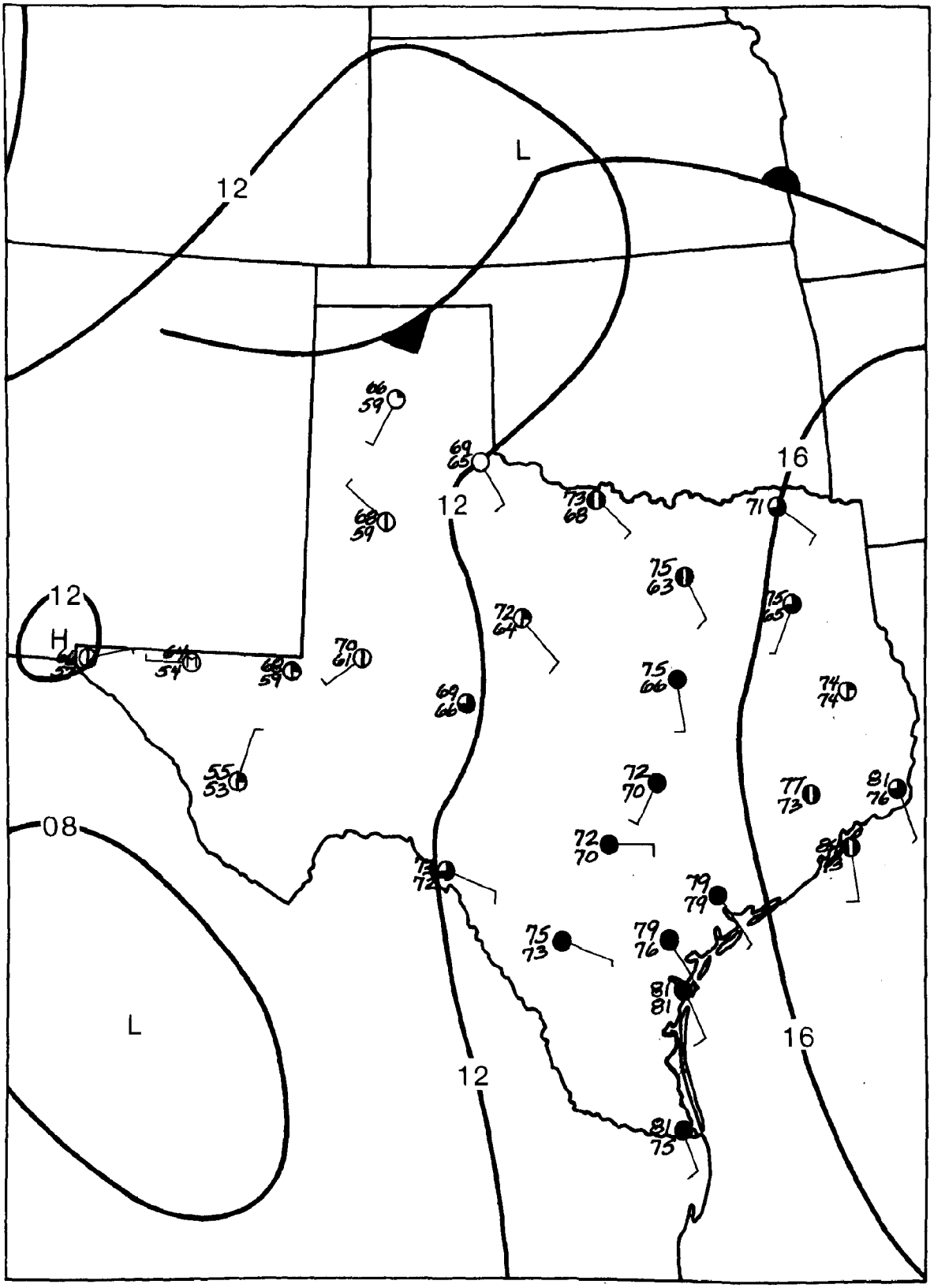



Figure 4.4 -- August 01-1200 GMT Surface Analysis.

Rainfall persisted Tuesday morning spreading additional amounts up to 2 inches northwestward. Tuesday morning satellite imagery shows the continued northwest moisture transport and accompanying rainfall. (See figures 4.6 and 4.7.) The August 01/1900 GMT SIM located the western edge of the low-level moisture along a San Angelo-Wichita Falls line.

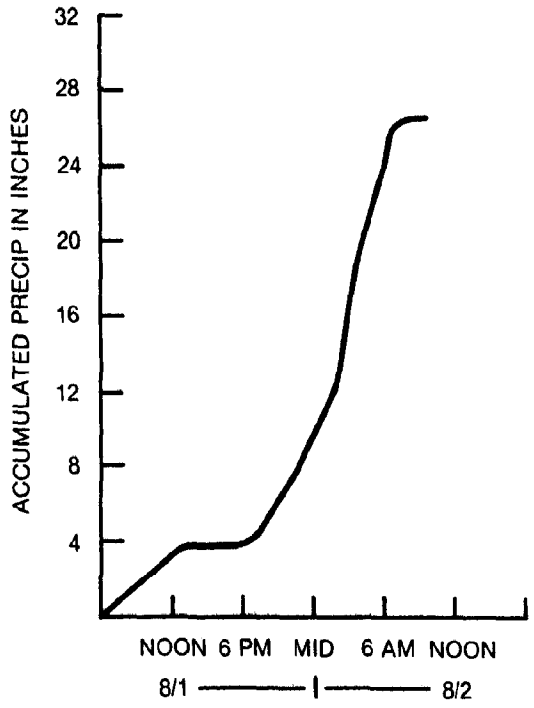
By 12:30 p.m. CDT, Kerrville had approximately 6 inches of rain, producing a rise on the Guadalupe River sufficient to activate the flash flood alarm upstream from Kerrville. This rainfall Monday night and early Tuesday primed the area where heavier rain would fall Tuesday night and Wednesday morning.

Radar data and satellite imagery showed a sharp decrease in convective activity early Tuesday afternoon. By early Tuesday evening there was little change in surface synoptic features, except for a front analyzed over the Panhandle Region, which had become stationary. But the LFM 500-mb analysis had moved the Mexico vorticity center to the Texas border, just south of Del Rio. Precipitable water amounts had now dropped below an inch and a half over the South Texas Coast, while a maximum of one and three quarters to 2 inches was analyzed over central Texas. During the evening, convection intensified over southern Texas and spread slowly northward toward the Hill Country. (See figure 4.8.)

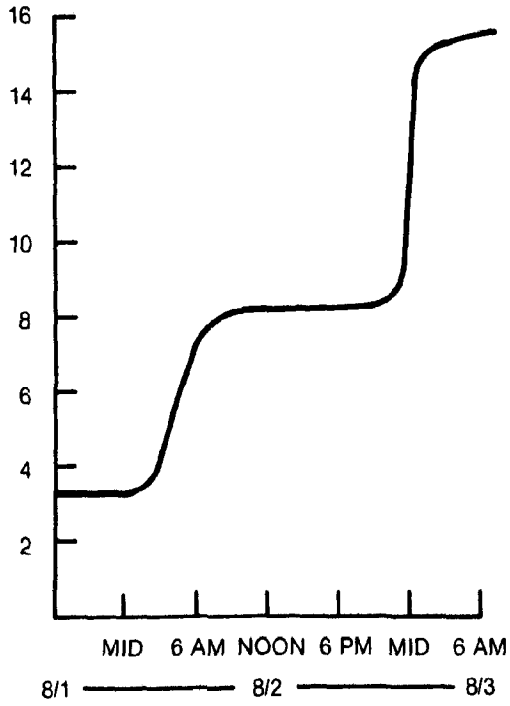
By 10 p.m. CDT, the large area of convection in south central Texas appeared to diminish, but by midnight Tuesday, new cells developed within the decaying area, about 40 to 50 miles west of San Antonio. The new area grew rapidly in size and intensity and spread very slowly northward through Bandera and Kerr Counties, producing the heaviest rainfall from 1:30 a.m. CDT to 6:30 a.m. CDT Wednesday. (See figures 4.9 - 4.16.) Medina, 4.5 miles west (figure 4.5.a), was near the center of heaviest rainfall. By 7 a.m. rainfall had diminished.

Increased dew points over west central Texas on the 1200 GMT surface analysis for Wednesday reflected increased low level moisture in that area. A precipitable water maximum of about one and three quarters inches remained over central Texas. The 1200 GMT surface map also shows the penetration of a cold front into Kansas and Colorado from the Northern Plains. The 1200 GMT LFM 500 mb analysis shows the continued northeast track of the vorticity center, from just south of Del Rio to just west of San Antonio. Rainfall continued in central Texas slightly north and northwest of the upper Guadalupe and Medina basins during much of Wednesday, but at a greatly reduced rate.

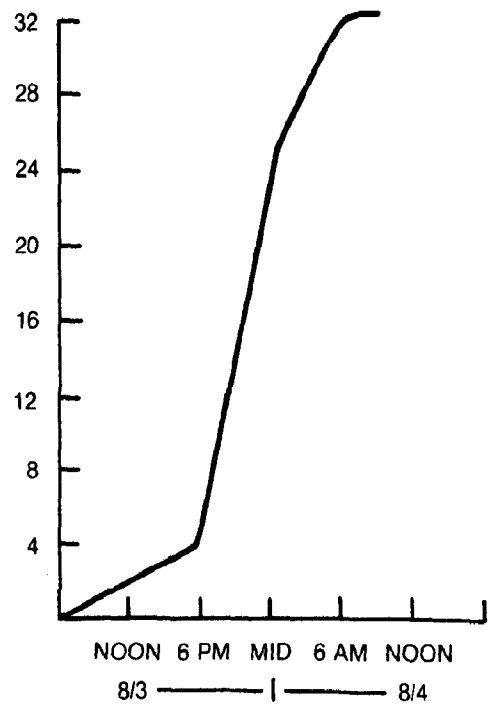
By 0000 GMT, August 3 (Wednesday evening), the Plains cold front had reached the Panhandle and the 500-mb vorticity center (as analyzed by the LFM) had turned to the northwest, moving from just west of San Antonio to just north of San Angelo. The 0100 GMT SIM from the Kansas City SFSS




A. MEDINA 4½ NW




B. HUNT 10 W




C. ALBANY 3 W

Figure 4.5 -- Mass Curves of Storm Precipitation.


Figure 4.6 -- August 01-1200 GMT EQIR.

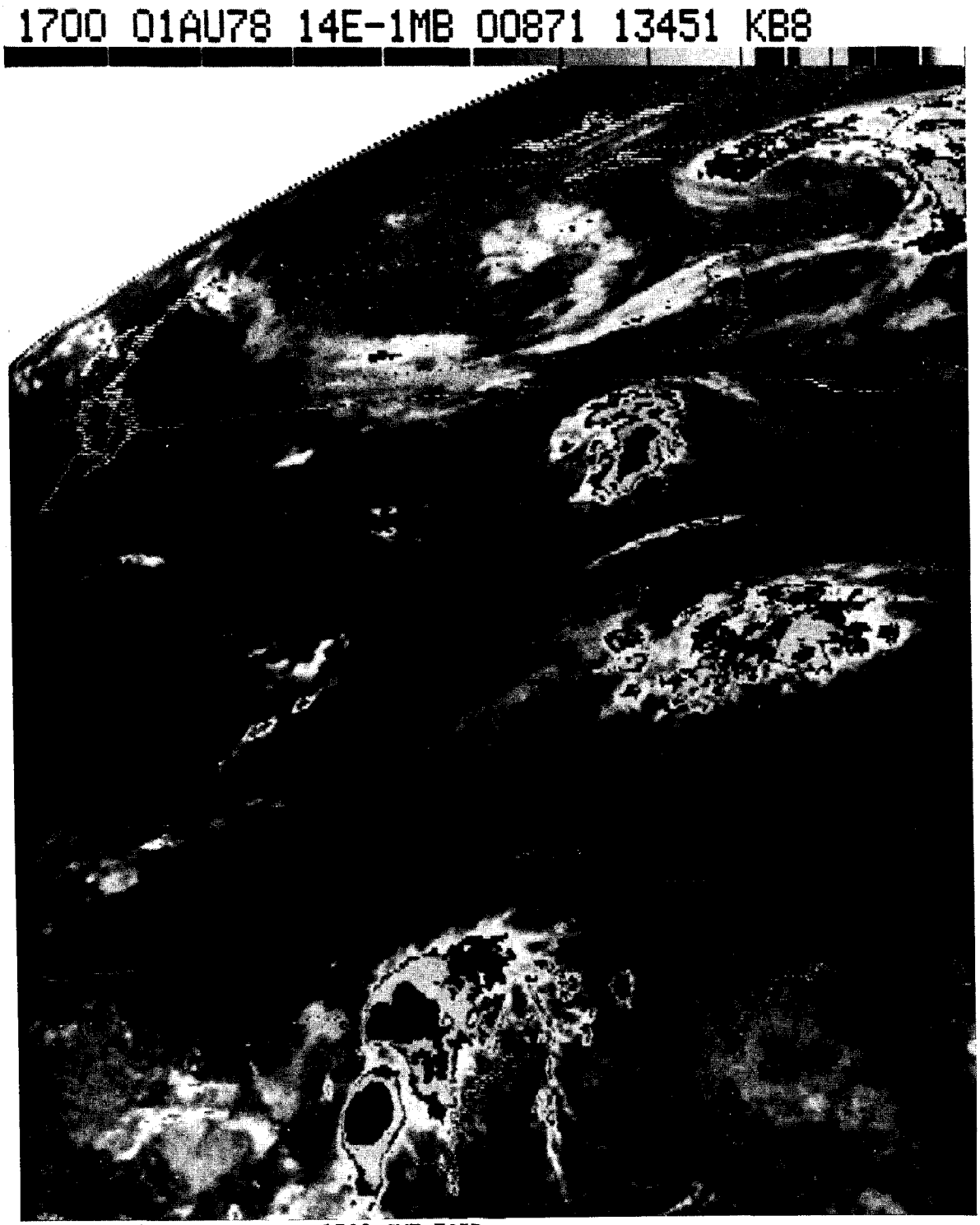



Figure 4.7 -- August 01-1700 GMT EQIR.

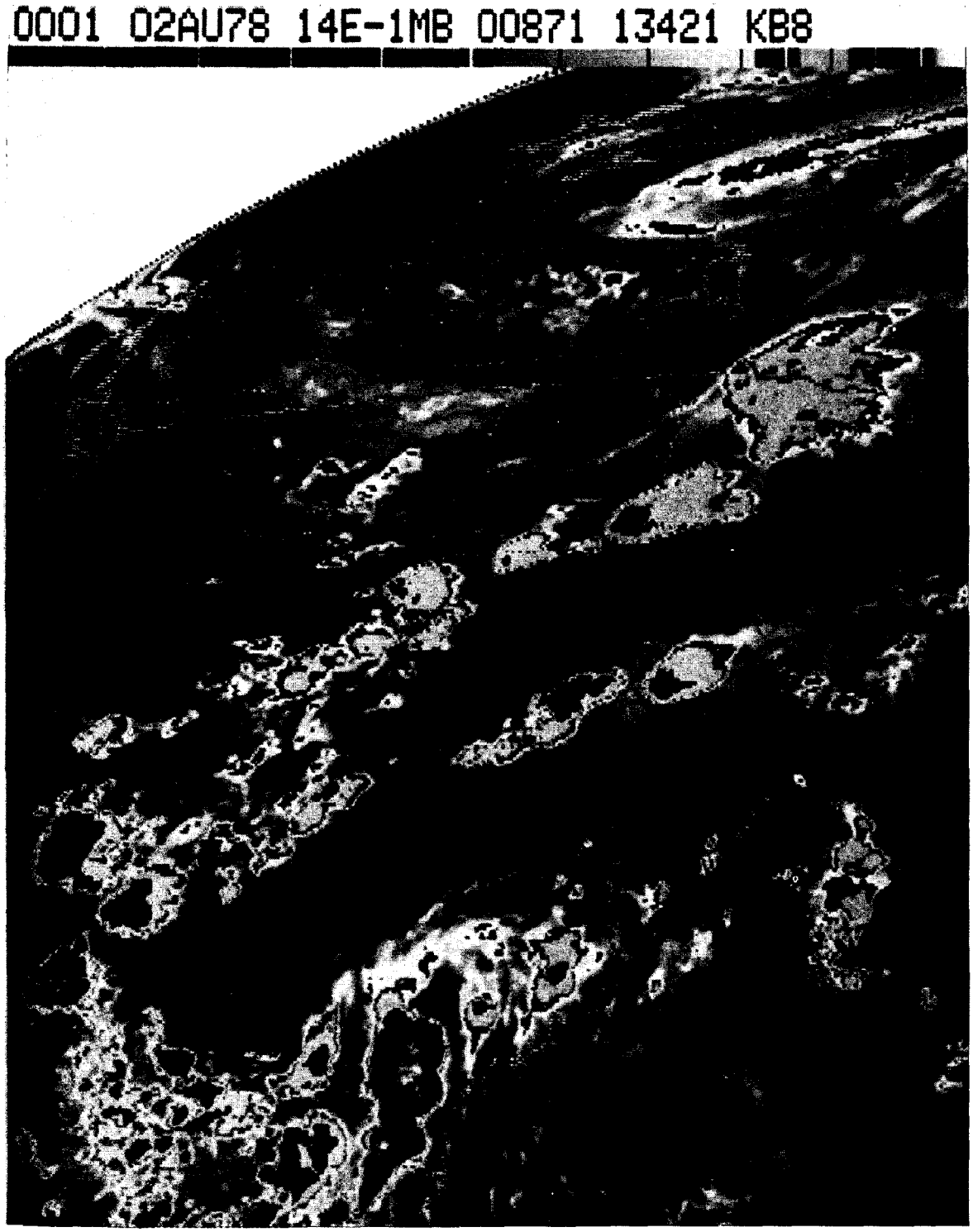



Figure 4.8 -- August 02-0000 GMT EQIR.

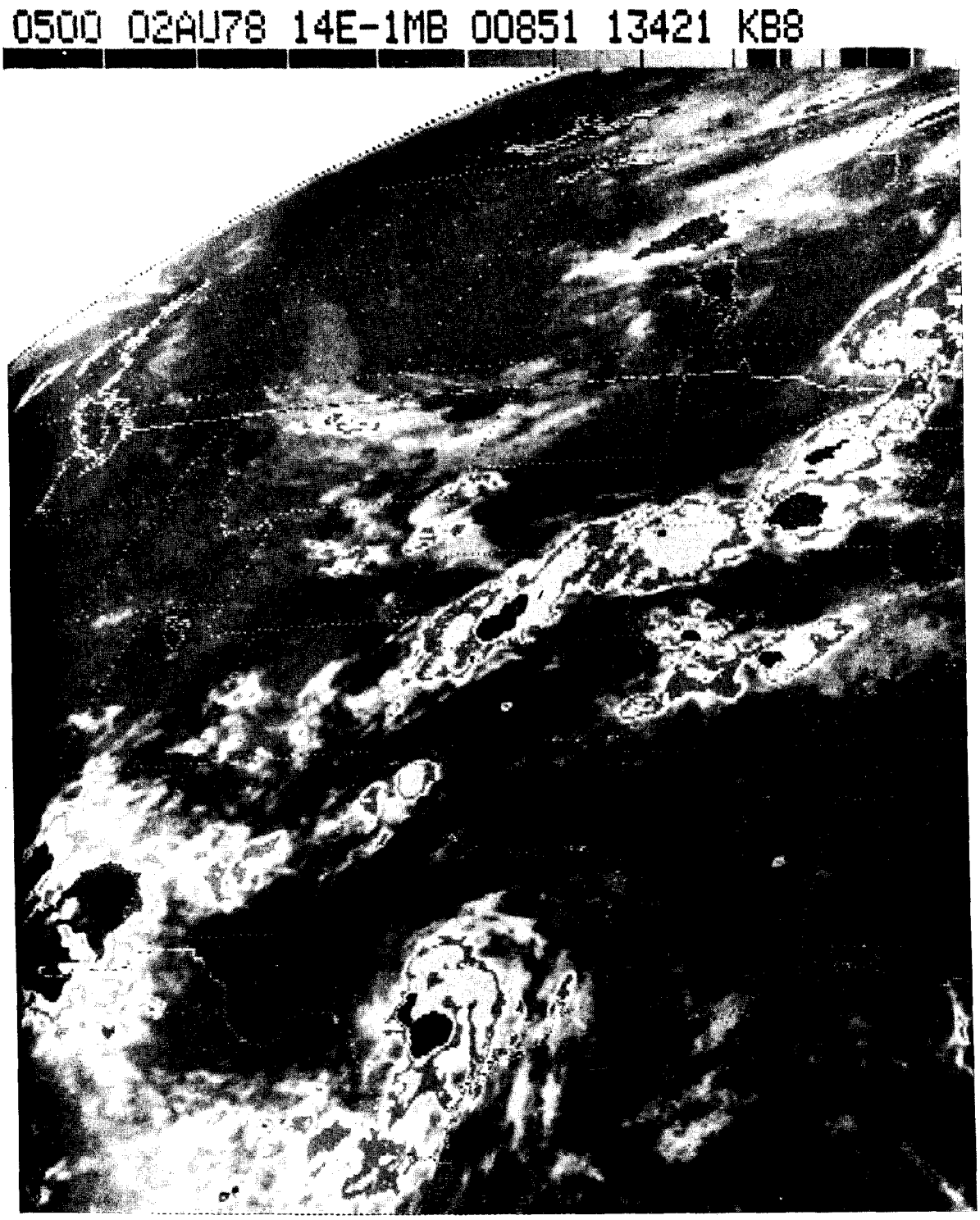



Figure 4.9 -- August 02-0500 GMT EQIR.


Figure 4.10 -- August 02-0700 GMT EQIR.


Figure 4.11 -- August 02-1000 GMT EQIR.


Figure 4.12 -- August 02-1100 GMT EQIR.

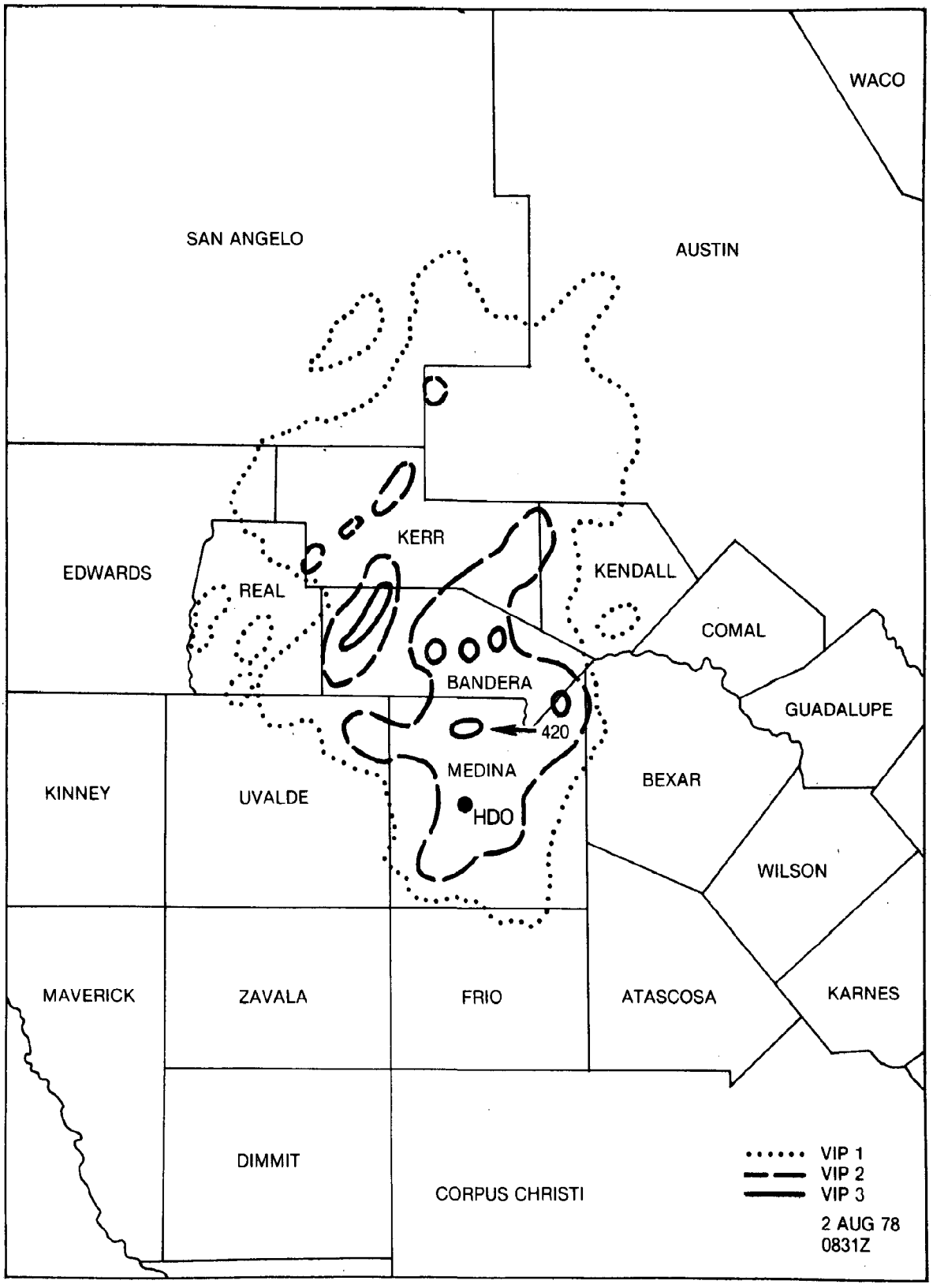



Figure 4.13 -- August 02-0331 CDT Hondo Radar Overlay,

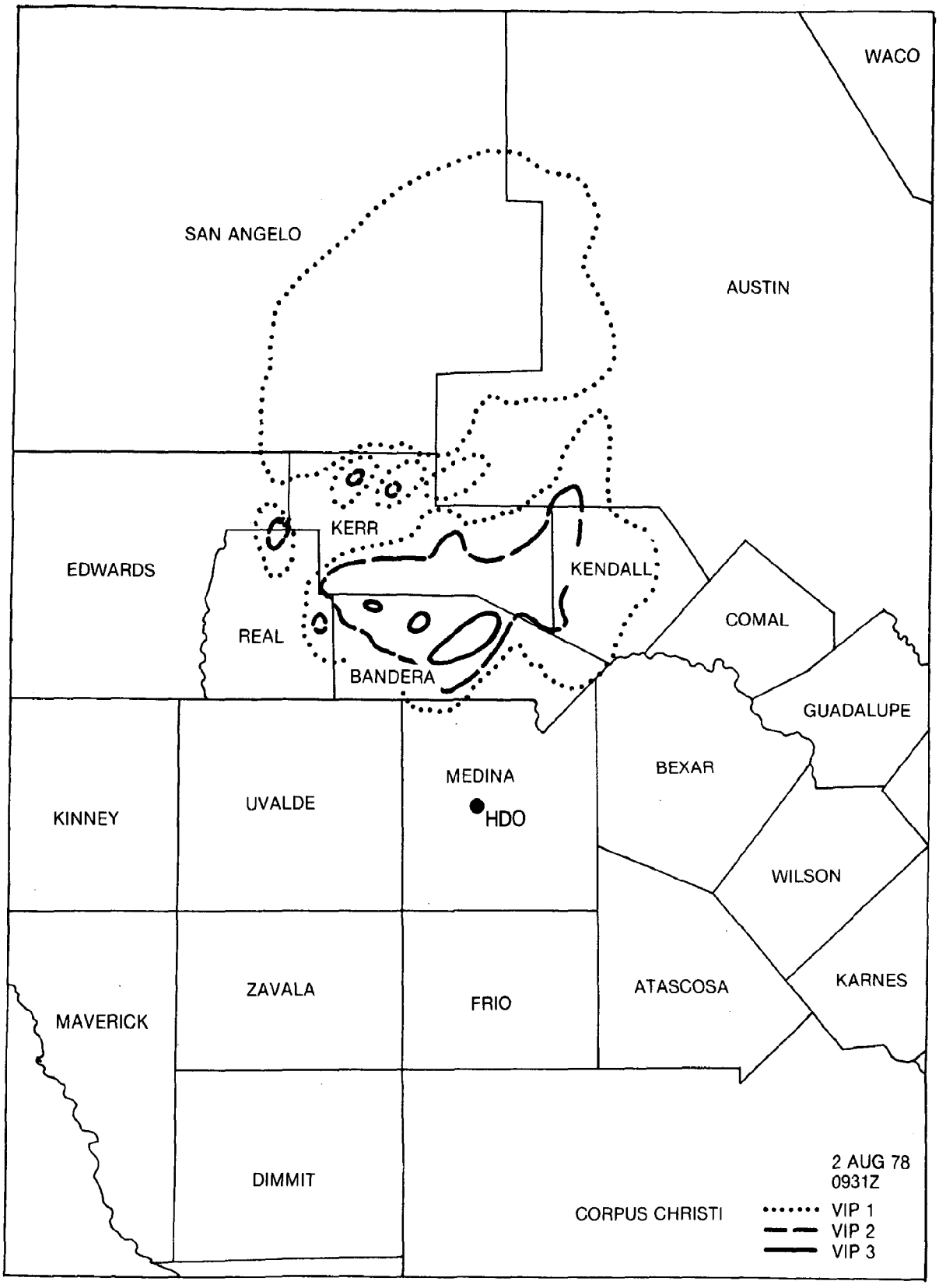



Figure 4.14 -- August 02-0431 CDT Radar Overlay.

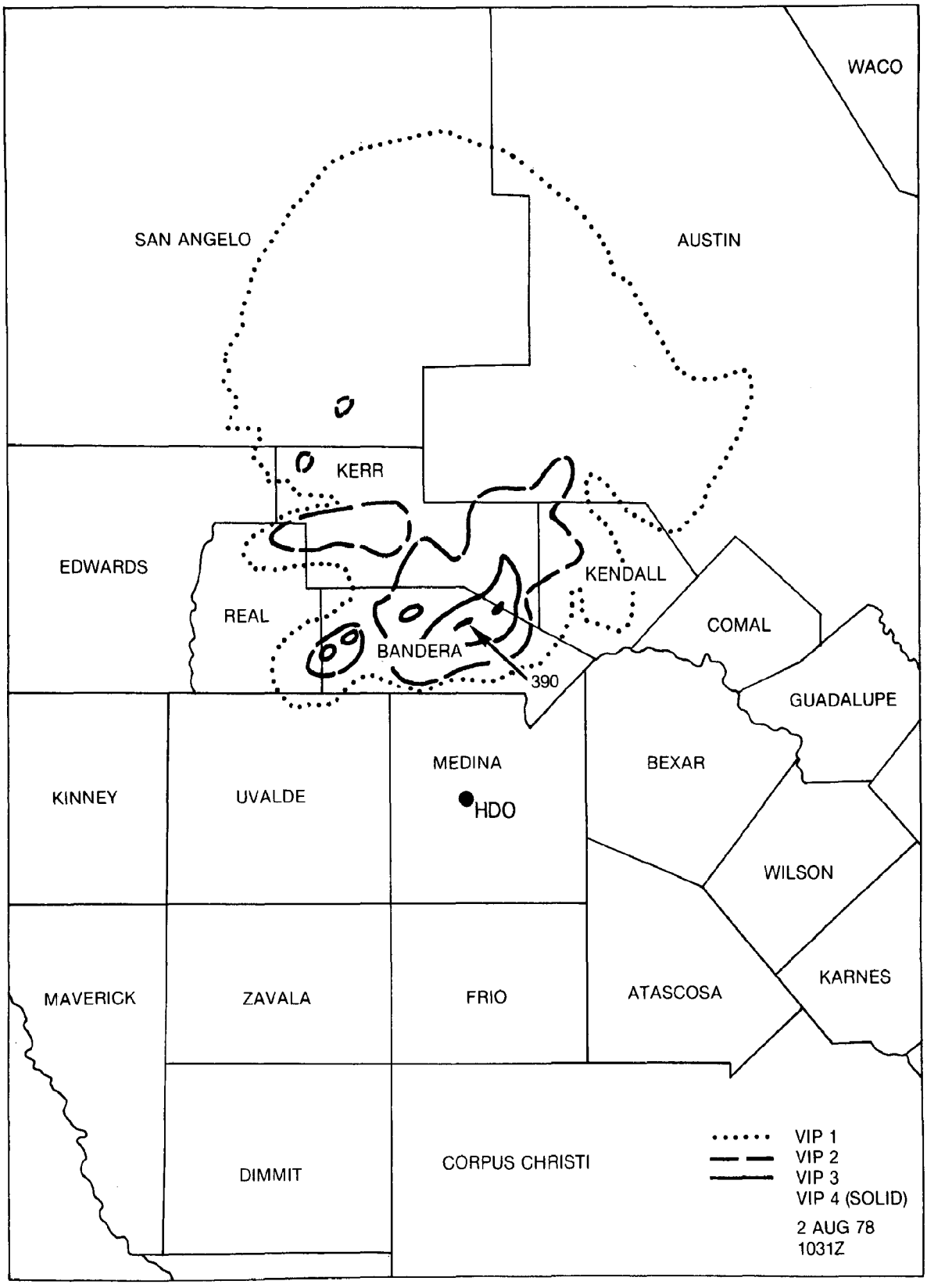



Figure 4.15 -- August 02-0531 CDT Radar Overlay.

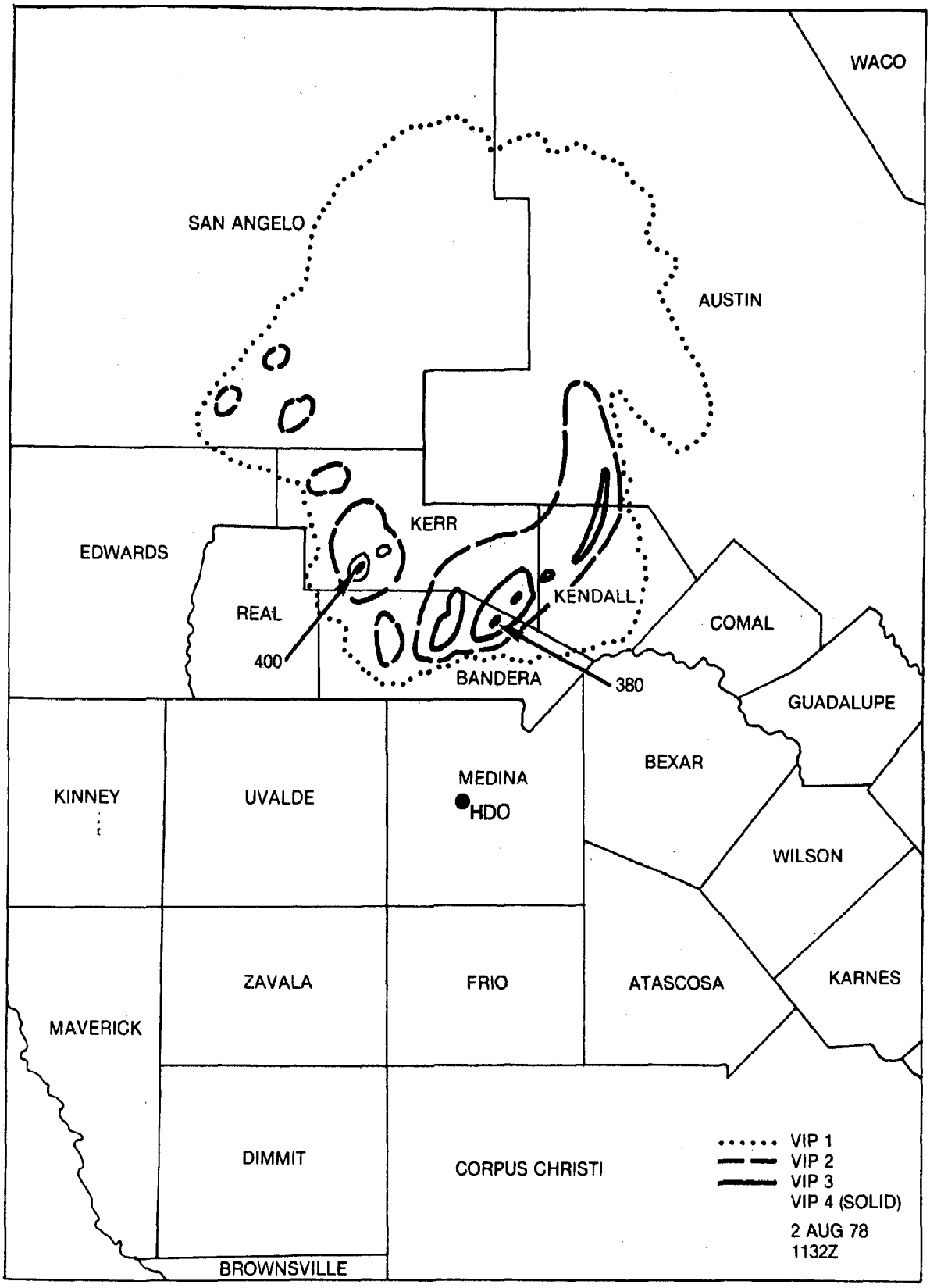



Figure 4.16 -- August 02-0632 CDT Radar Overlay.

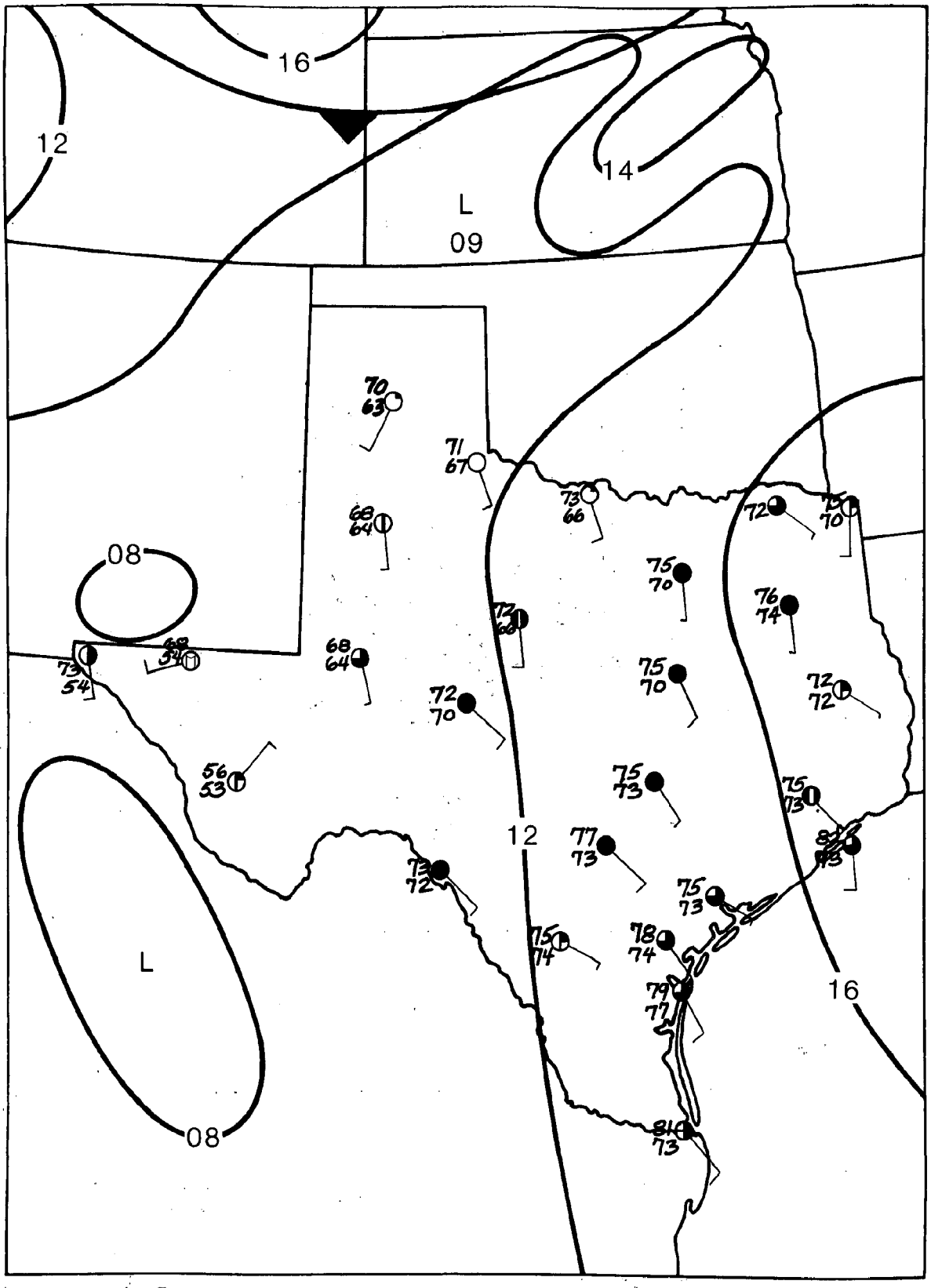



Figure 4.17 -- August 02-1200 GMT Surface Analysis.

positioned the vorticity center near Brownwood, slightly east of the LFM analysis. Rainfall that persisted just north and northwest of the Upper Guadalupe and Medina basins during the day diminished by 10:30 p.m. CDT, as new convection was developing in an area of abundant low-level moisture, along a line just west of Laredo and Cotulla, through Bandera and Kerr Counties (see figures 4.18 - 4.22). Very heavy rainfall occurred over the same area at roughly the same time as the night before. A rainfall station 10 miles west of Hunt in the Upper Guadalupe Basin (figure 4.5.b) received 7.5 inches during this burst. Nearby Ingram received an additional 14 inches.

The heavy rain began to diminish over the Hill Country by 6 a.m. CDT Thursday, but another area of very strong convection had already developed from around San Angelo through Abilene and into the Albany area (see figure 4.23). The surface front in the Panhandle region had now become stationary, extending from just south of the Panhandle along the Texas-Oklahoma border into central Arkansas. The 1200 GMT LFM 500-mb analysis positioned the vorticity center between Midland and Abilene, while the 1300 GMT SIM noted a high level rotational center just north of Abilene.

The convection east of San Angelo through the Abilene area produced as much as 6 to 8 inches of rain by midmorning. There was some decrease in intensity later in the morning, but rainfall continued in the area through much of the day. Reintensification began over the Albany area late Thursday afternoon and continued through the evening (figure 4.5.c). The August 4, 0100 GMT SIM indicated that an oscillating upper Low and vorticity maximum was about 30 miles northwest of Abilene with convection most active from between Abilene and Fort Worth southwestward to near San Angelo and down to the Big Bend (see figures 4.24 - 4.27). Heavy rains spread northward Thursday night, diminishing slowly through early morning.

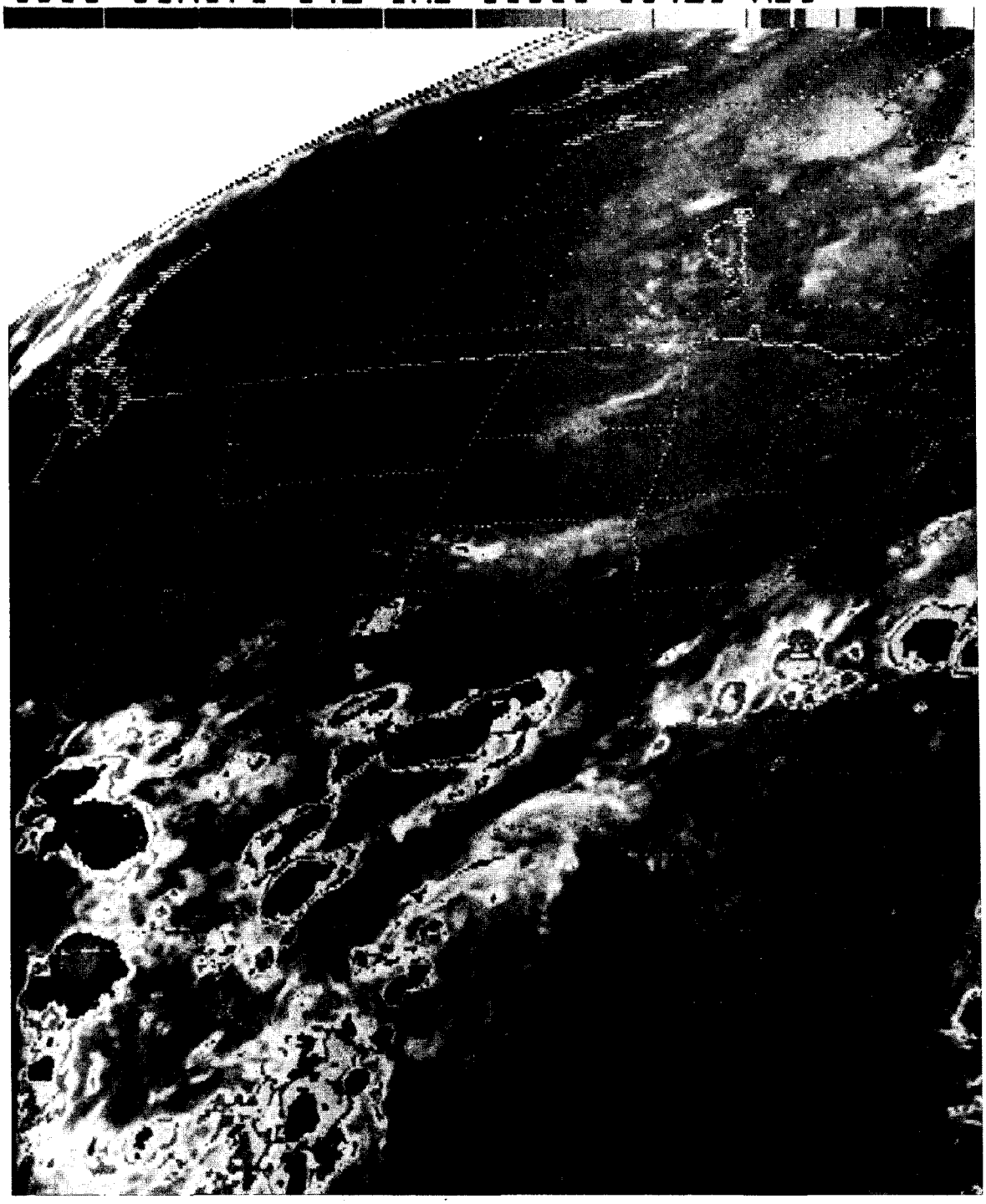



Figure 4.18 -- August 03-0330 GMT EQIR.

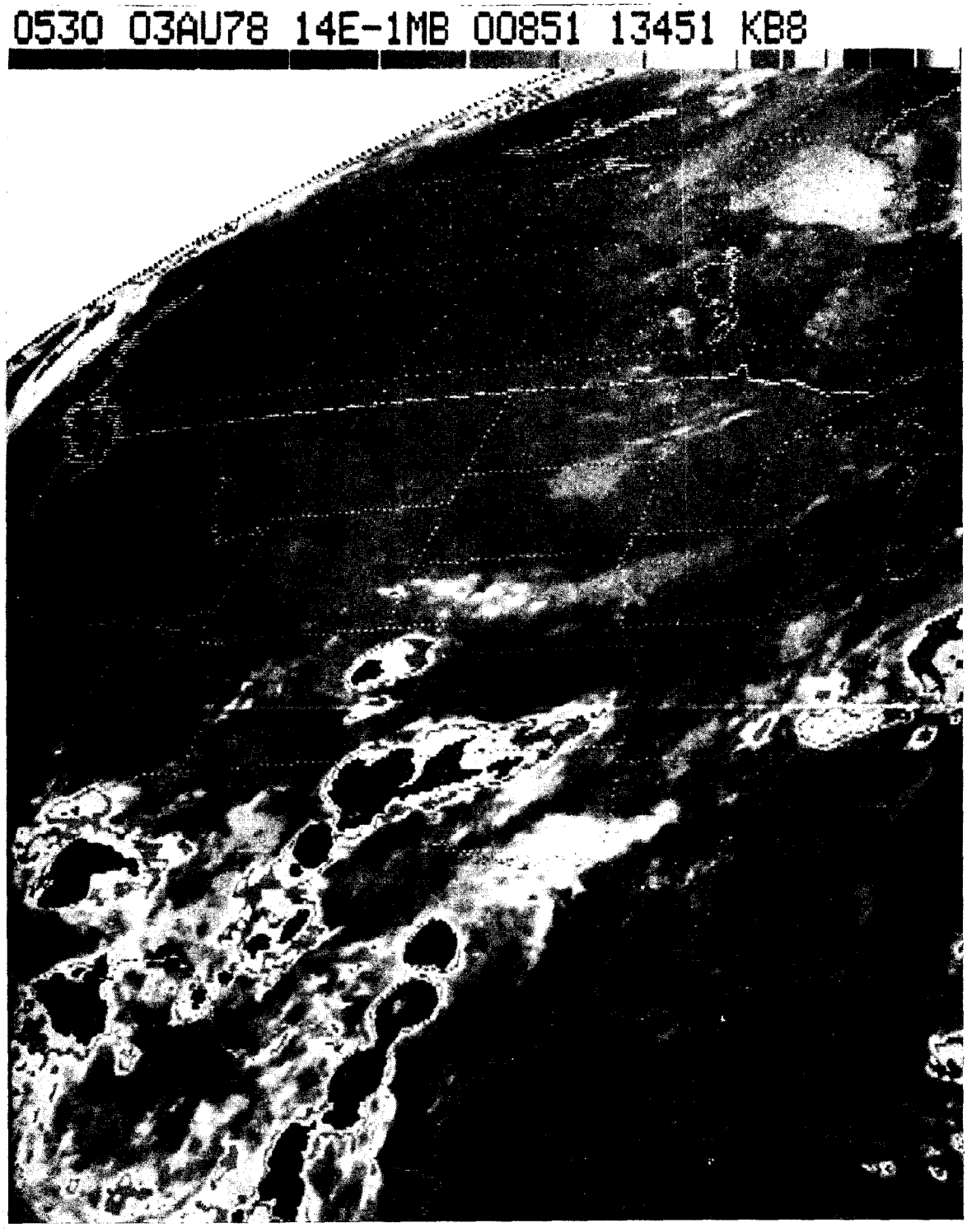



Figure 4.19 -- August 03-0530 GMT EQIR.

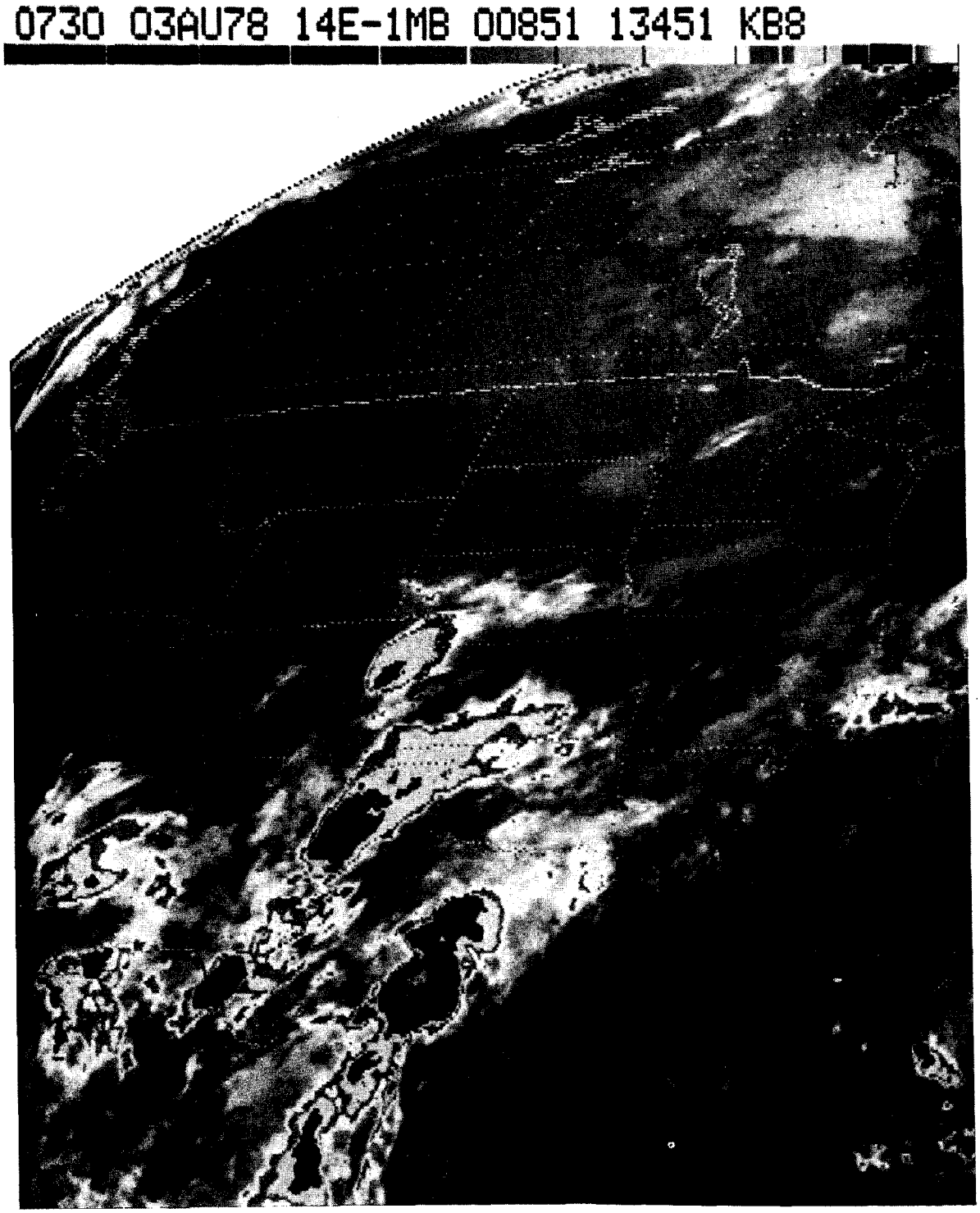



Figure 4.20 -- August 03-0730 GMT EQIR.

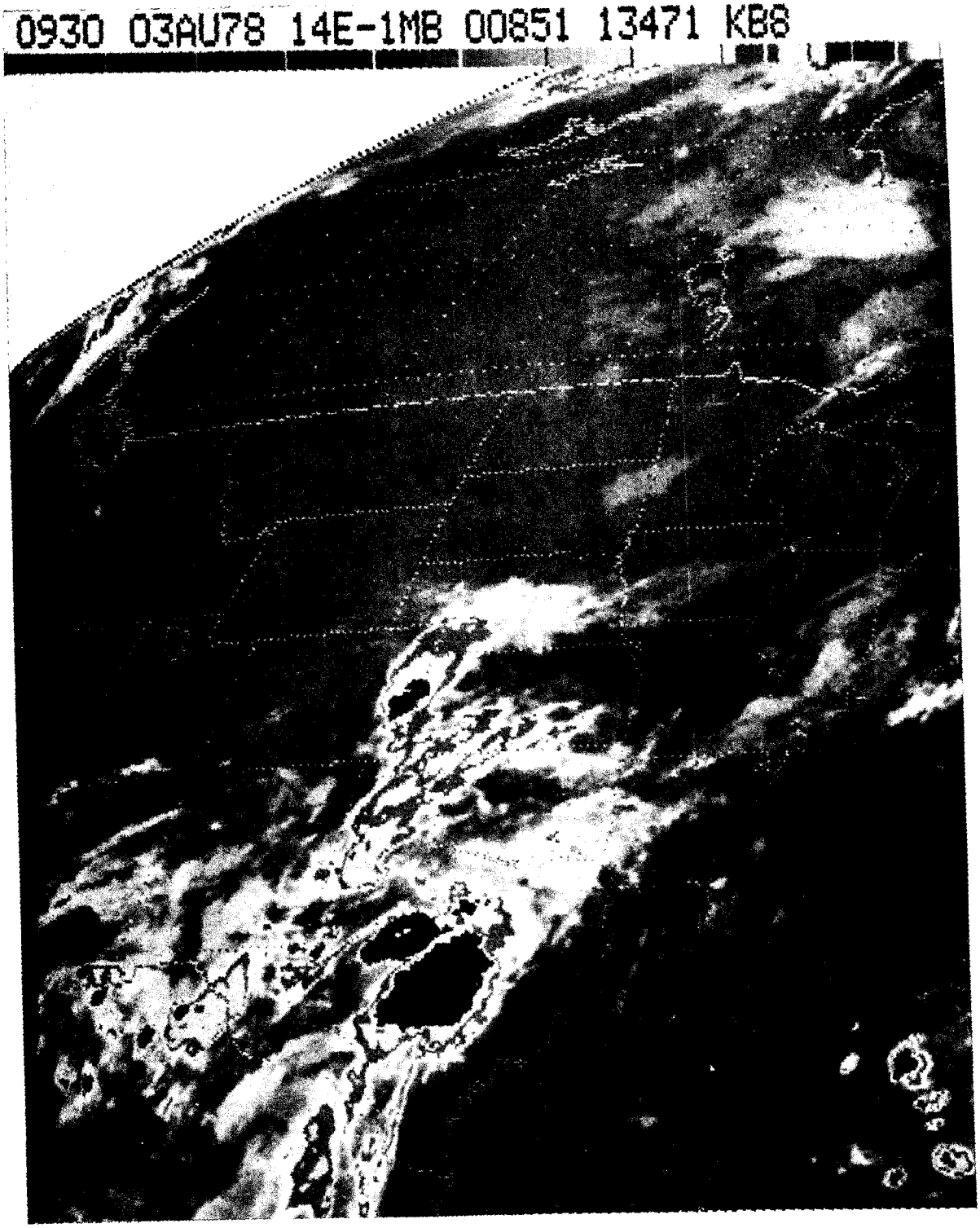



Figure 4.21 -- August 03-0930 GMT EQIR.

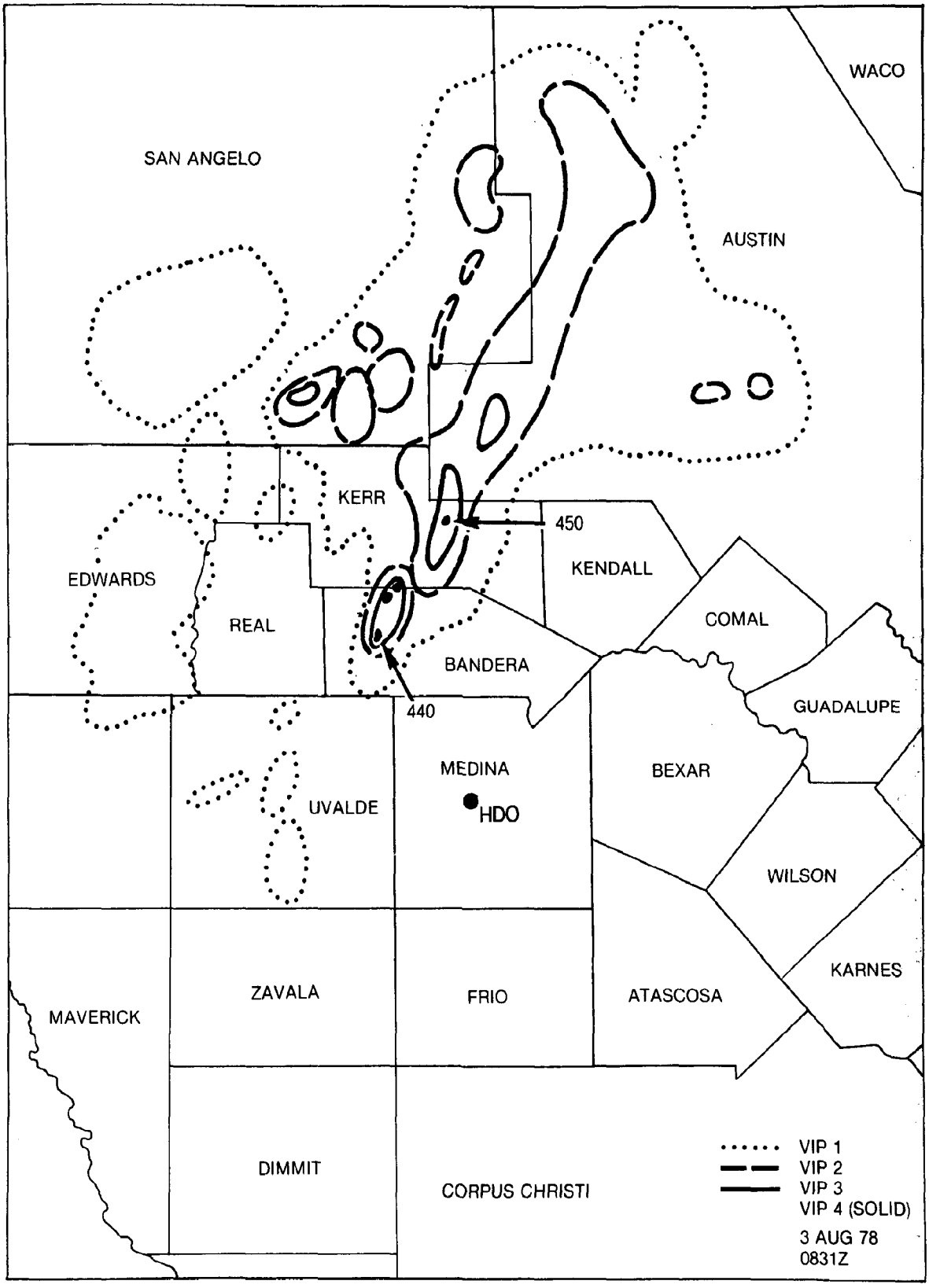



Figure 4.22 -- August 03-0331 CDT Radar Overlay.

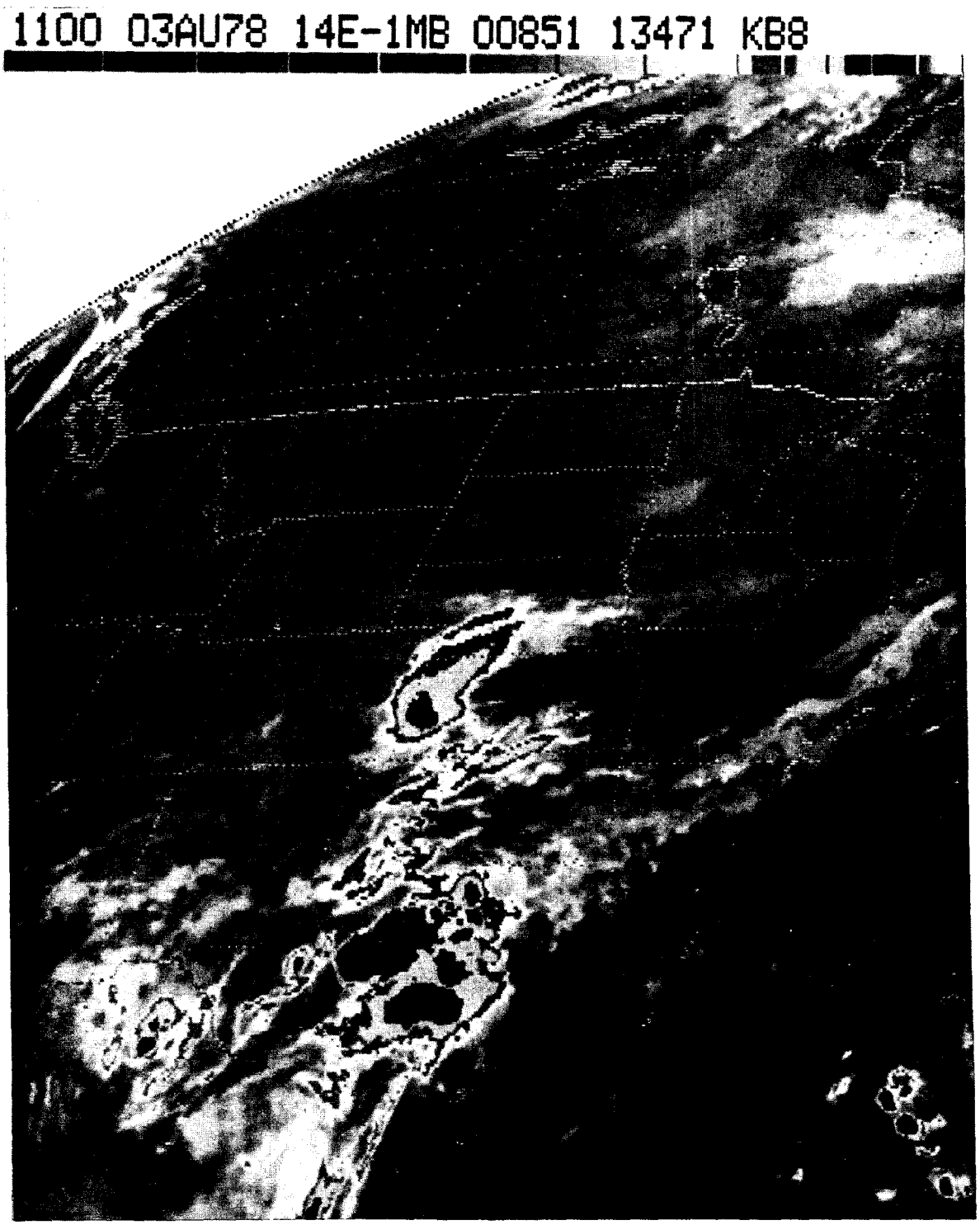



Figure 4.23 -- August 03-1100 GMT EQIR.

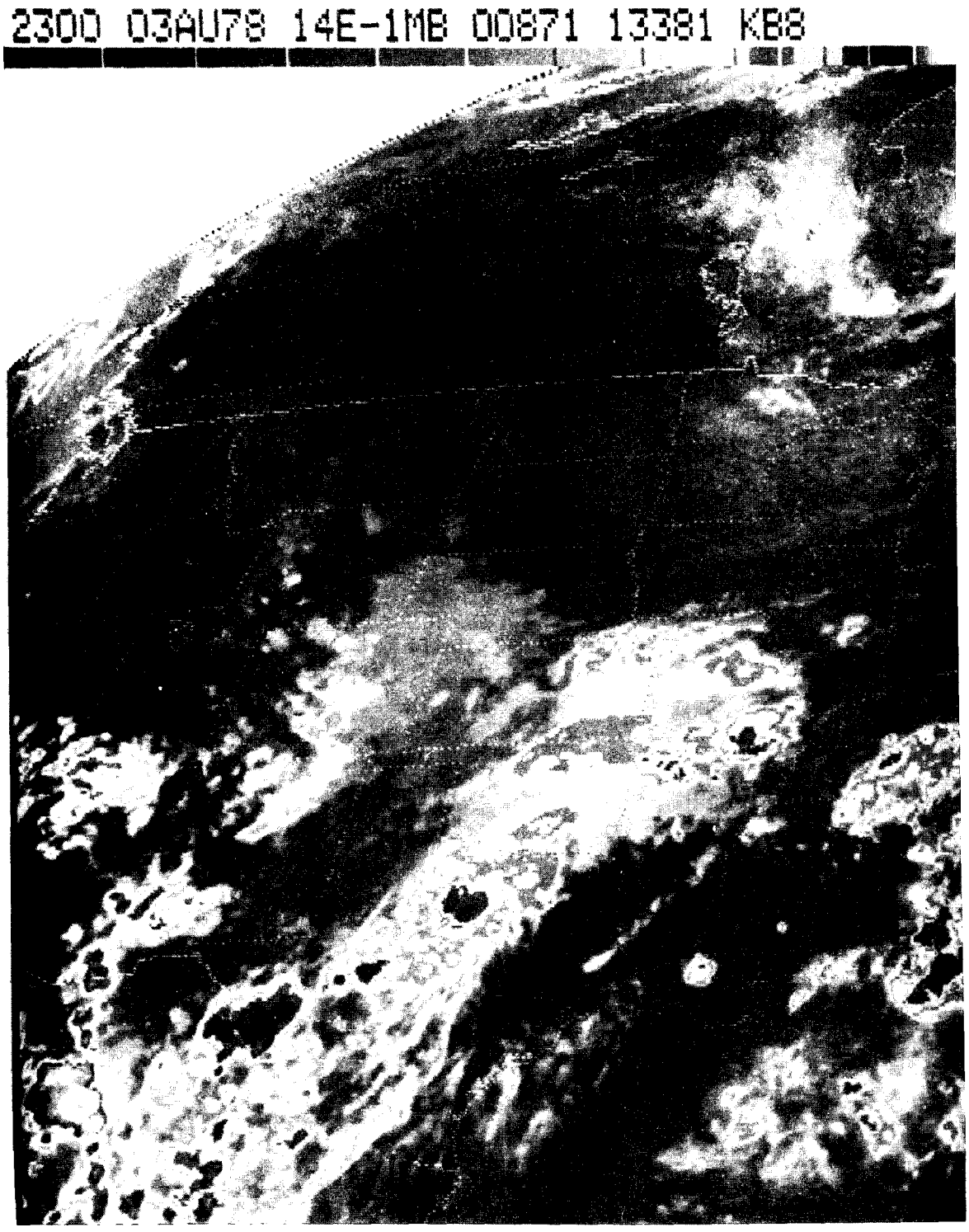



Figure 4.24 -- August 03-2300 GMT EQIR.

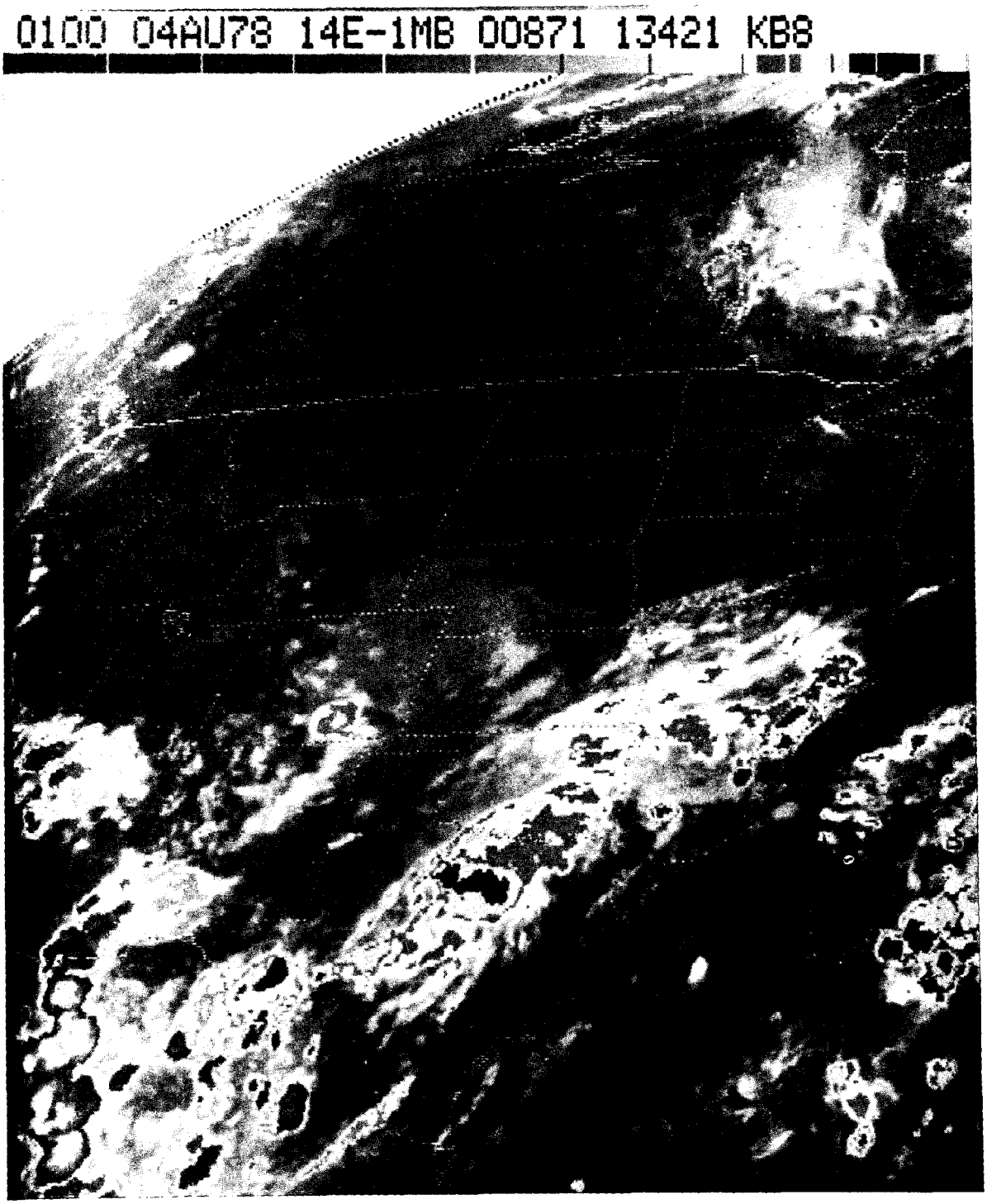



Figure 4.25 -- August 04-0100 GMT EQIR.

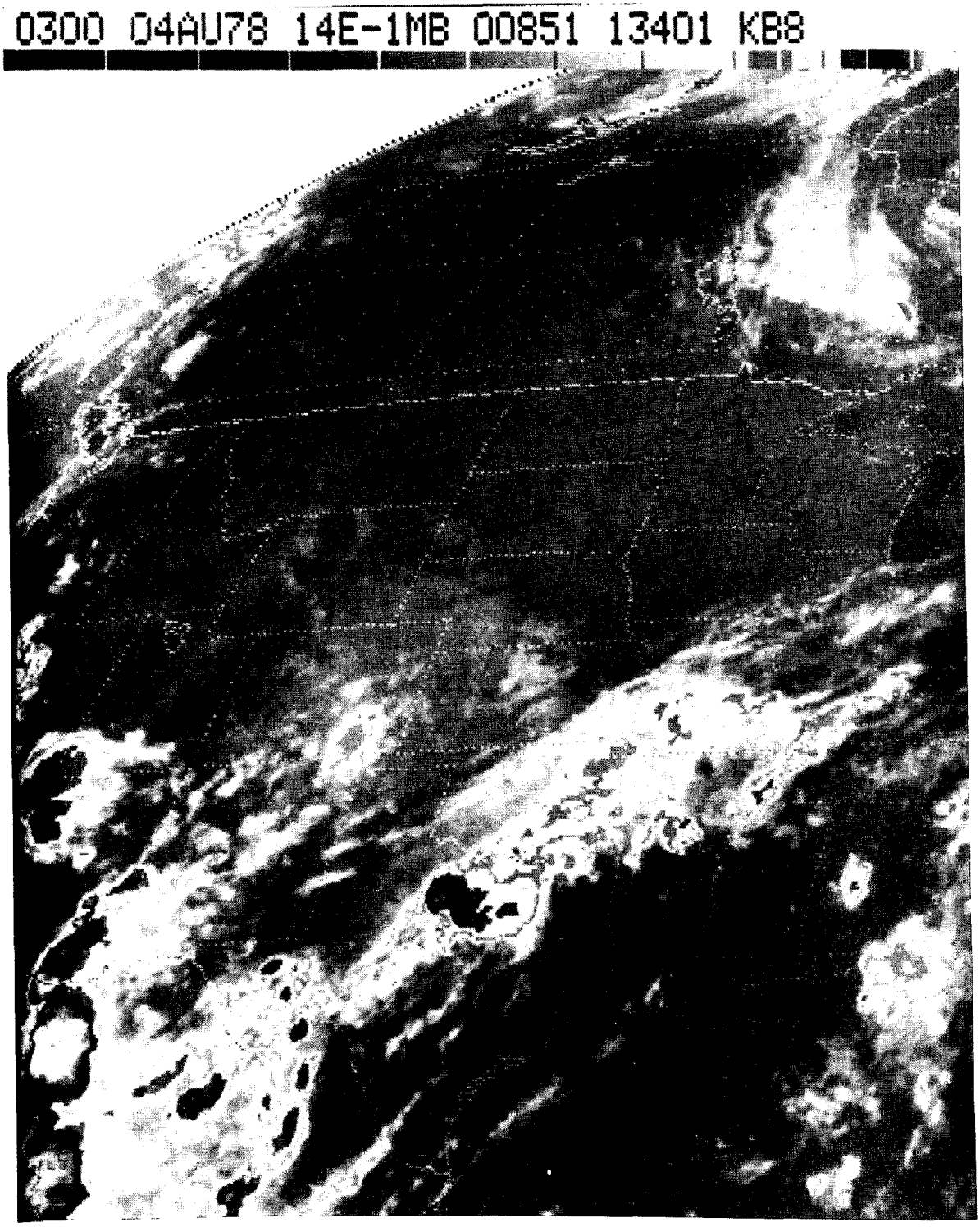



Figure 4.26 -- August 04-0300 GMT EQIR.

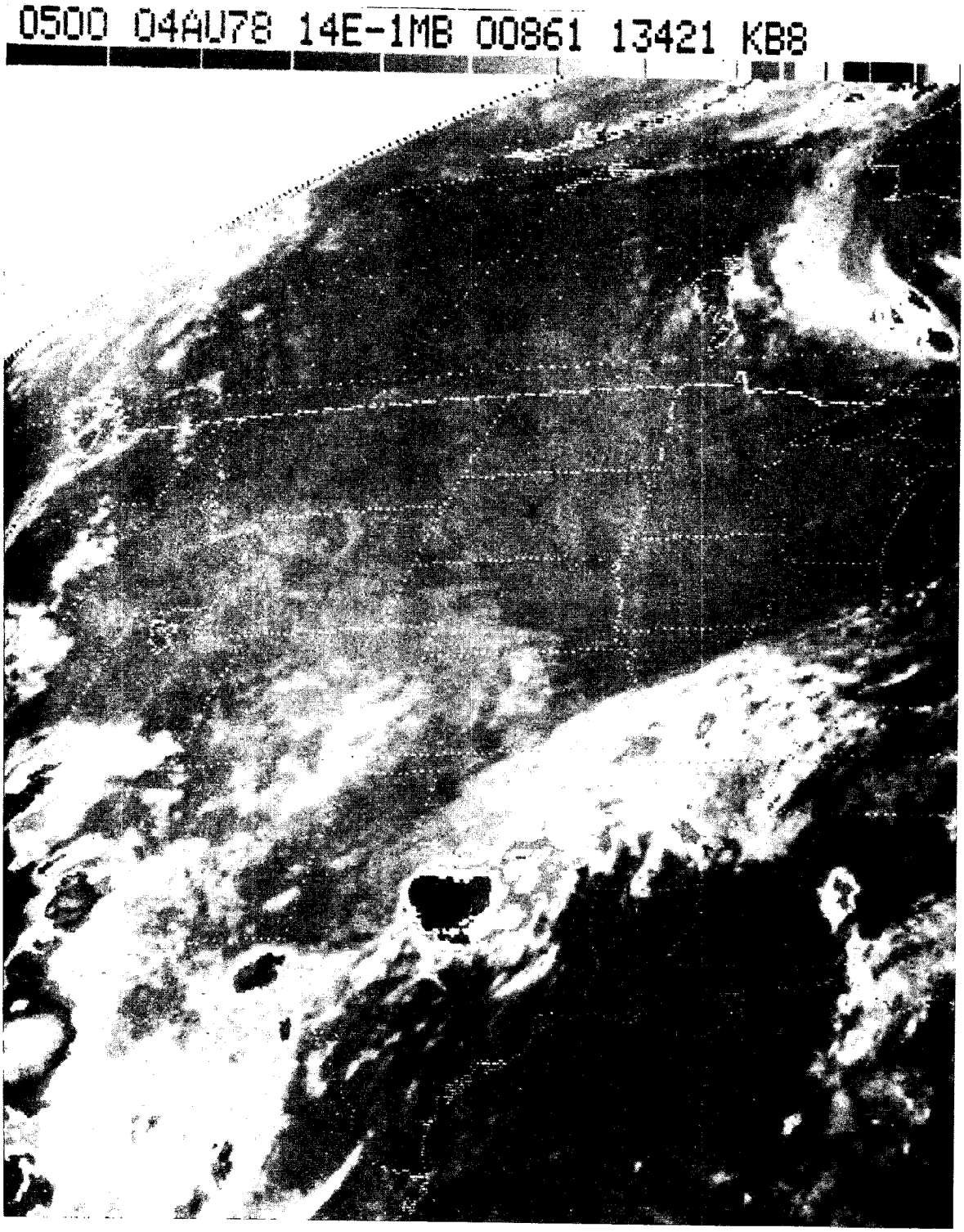



Figure 4.27 -- August 04-0500 GMT EQIR.

# CHAPTER 5

## GUIDANCE MATERIAL AVAILABLE TO FORECAST OFFICES

In addition to radar, satellite, surface, and upper air data, field offices are provided forecast guidance from several numerical models run on computers at the National Meteorological Center (NMC) in Washington, D.C. Output from these models is also used by meteorologists in NMC's Basic Weather and Aviation Weather Branches to make 12-, 24-, 36-, and 48-hour subjective (hand-drawn) synoptic forecasts for the United States and by forecasters at NMC's Quantitative Precipitation Branch (QPB) to prepare subjective quantitative precipitation forecasts (QPFs).

The routine numerical models (Barotropic, LFM II, 7-layer PE, and Trajectory) are run twice each day, after data times of 0000 GMT and 1200 GMT. Results are sent to NWS offices over facsimile networks and teletypewriter circuits starting two and one half to three hours after the data times. Each model's output consists of forecasts of many meteorological parameters computed over grids which vary in size and resolution. The LFM II and 7-layer PE models each produce a full range of parameters (including quantitative precipitation, surface pressure, relative humidity, and 500 mb heights and vorticity), while the barotropic and trajectory models deal with just a few. The LFM II became operational in late August 1977. It is the highest resolution routinely run model at NMC. Its grid size is 127 km at 60°N. The original LFM grid was 190.5 km. The 7-layer PE model went into daily use in January 1978. Its grid size is half that of the 6-layer PE and is equal to the size of the original LFM grid. Generally, as grid size is reduced, forecasts improve but greater computer capacity is needed.

Statistical methods are applied to the output from each run of the LFM II and 7-layer PE models to arrive at forecasts of additional parameters for approximately 230 specific locations in the United States. The process is referred to as the Model Output Statistics (MOS) method. Two of the MOS parameters are Probability of Precipitation (PoP) and Probability of Precipitation Amount (PoPA).

In addition to the routine operational models, a higher resolution smaller area model, the Moveable Fine Mesh (MFM) model became operationally available on request in June 1976. The MFM grid is only 60 km at 60°N during the summer and 100 km in winter. It is run on request from NMC to produce numerical QPFs in hurricane and other heavy precipitation events. The MFM model cannot be run routinely because of NMC computer capacity limitations.

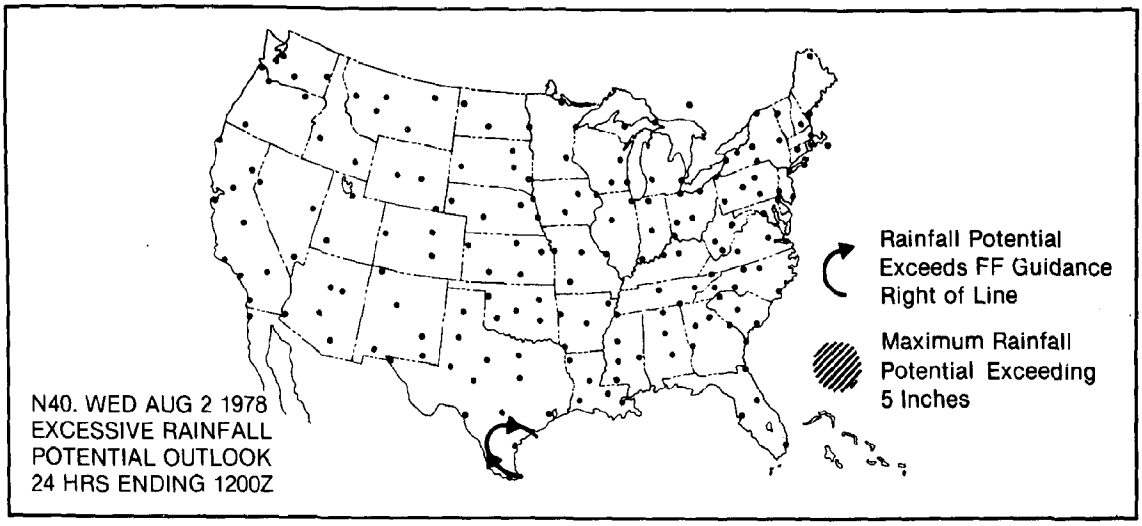
In spite of the improvements in the resolution of NMC operational models and the increase in tailored MOS forecasts, most mesoscale systems and convective elements that contribute to significant flash flood events are

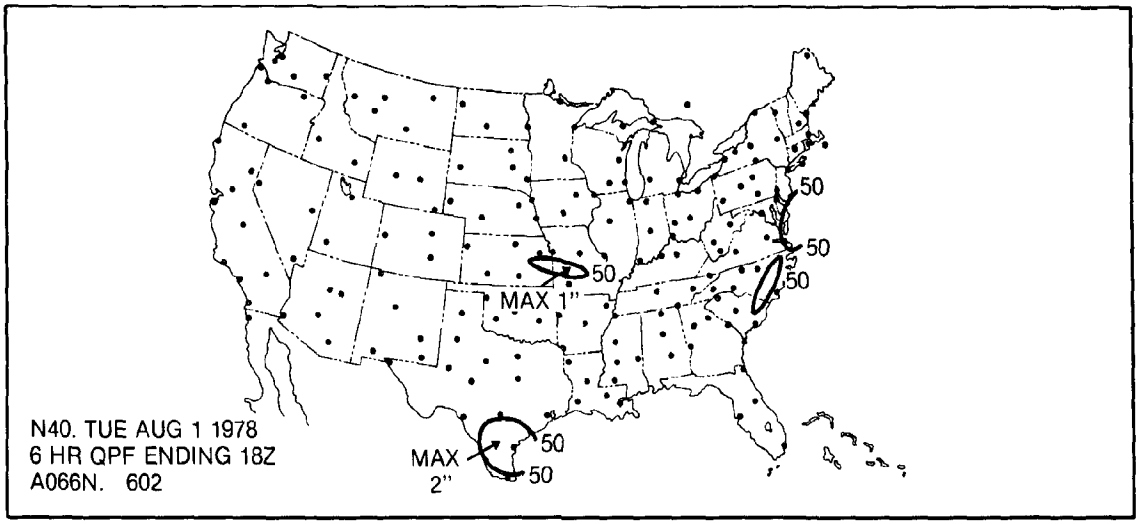
too small scale to be consistently and accurately forecast by current numerical methods. This includes the MFM. In this case, the models forecast precipitation east of the actual rainfall maxima early in the week of July 31. The MFM was requested by QPB on Sunday night, July 30, and it too placed maximum precipitation areas too far east, although amounts were much higher than indicated by the routine operational models. LFM II and 7-layer PE QPFs frequently contained the areas of heaviest actual rainfall within forecast areas of measurable precipitation, but forecast maxima were generally too far east and too low. The models indicated Amelia would move inland along the south Texas coast and proceed northeastward along the coast, carrying the heaviest precipitation toward southwest Louisiana. Additional MFM model runs made after the fact on data observed during the storm also showed little skill in handling the situation.

In late July 1978, NMC's Quantitative Precipitation Branch started a new program of incorporating RFC flash flood guidance with QPB precipitation forecasts. The goal of the new program is to provide accurate spatial and temporal predictions of excessive rainfall. Subjective QPFs are transmitted four times a day over the facsimile networks. Two transmissions contain only 24-hour forecasts, while the other two give forecasts of rainfall potential exceeding flash flood guidance. Maximum amounts are frequently included. The QPB also sends narrative messages over the RAWARC teletypewriter circuits. Most of these coincide with the facsimile maps, but unscheduled messages may be issued to relay critical updates. Additional guidance is available 24 hours per day from the QPB forecaster by telephone.

Although it may not have made a major change in the NWS watches and warnings, one QPB problem was the receipt of the rainfall reports available to field offices. The QPB telephone log shows only two coordination calls from WSFO San Antonio and one from WSFO Fort Worth. In addition to telephone calls from WSFOs, QPB receives reports of surface observations over teletypewriter circuits plus reports included in warnings and statements sent by NWS field offices on RAWARC. In this situation, much of the heaviest rain fell between stations in the comparatively sparse surface observation network.

QPB subjective forecasts generally followed the numerical guidance early in the week by placing precipitation maxima too far east. The forecasts improved dramatically early Wednesday morning in their locations for the heaviest rainfall, although forecast amounts remained comparatively low. (See figures 5.1 and 5.2.) The subjective synoptic forecasts prepared at NMC also improved by Wednesday, but precipitation was underforecast in this guidance as well.



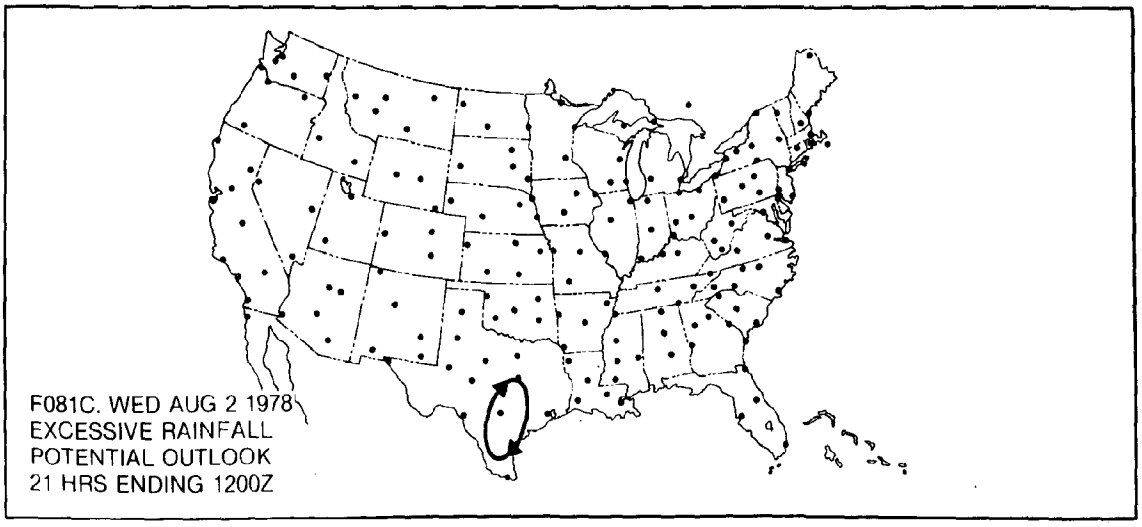
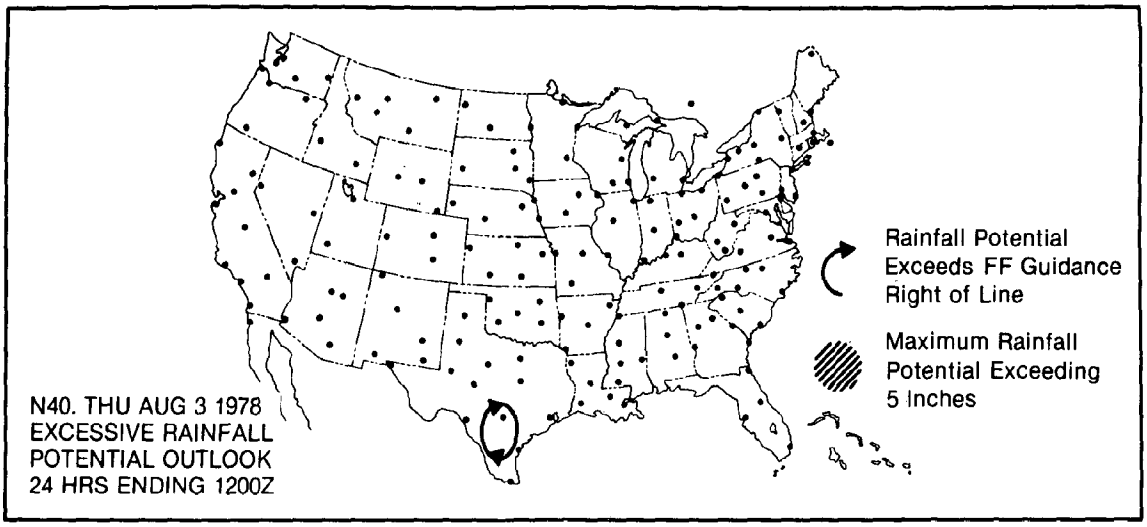
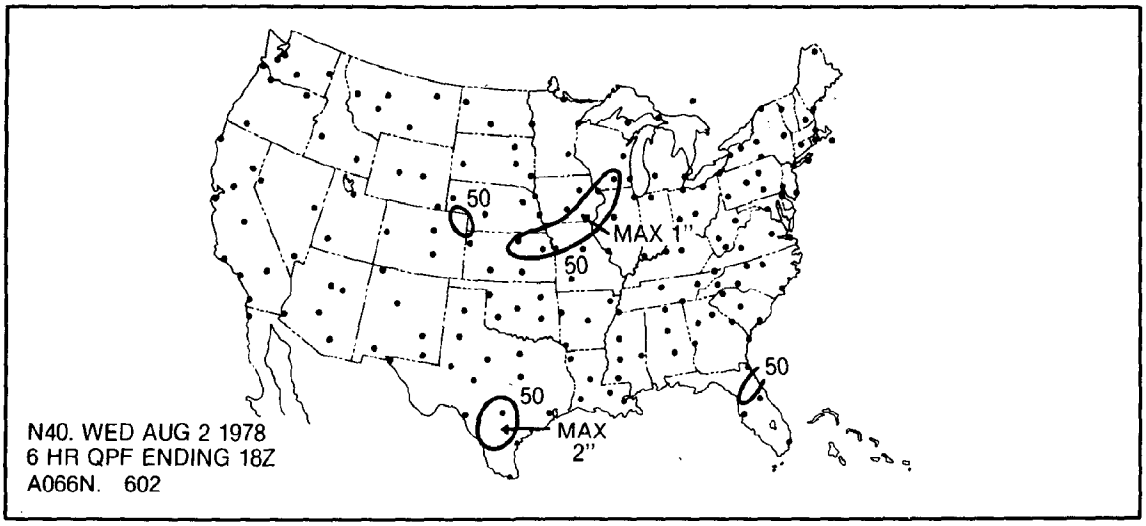




Figure 5.1 -- QPF Guidance Prepared August 1, valid August 1 and 2.



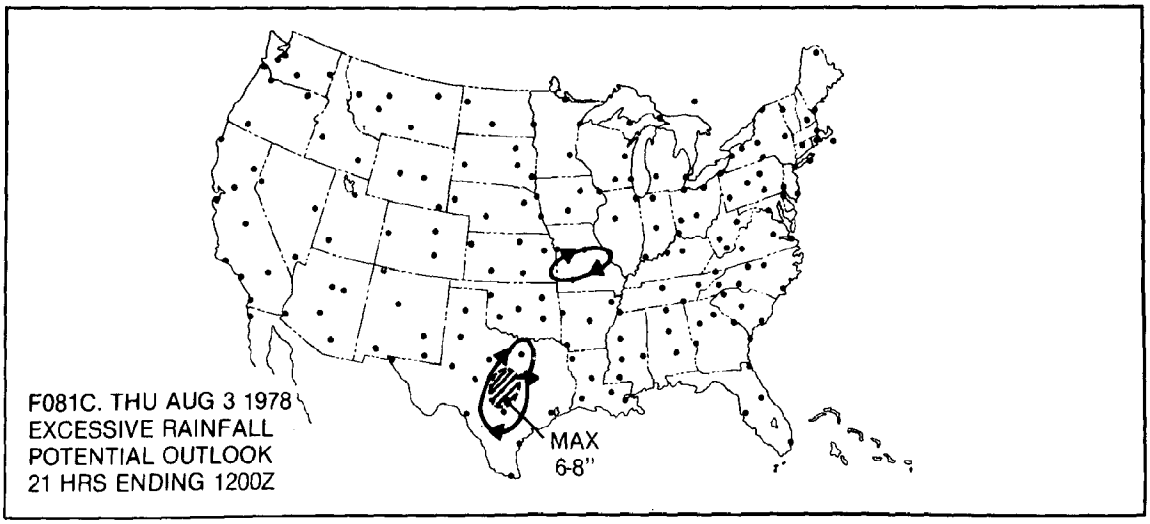




Figure 5.2 -- QPF Guidance Prepared August 2, valid August 2 and 3.

## FINDINGS AND RECOMMENDATIONS

### Finding 5.1

Forecast guidance from NMC was not particularly helpful in pinpointing excessive rainfall areas early in the week of July 30. Subjective forecasts improved somewhat by the middle of the week.

### Recommendation 5.1

Development of models and techniques to help in forecasting very heavy rains should be continued and given priority for expanded effort.

### Finding 5.2

Quantitative Precipitation Branch (QPB) lacked real time rainfall reports from the field. While this did not significantly affect the watches and warnings issued by WSOs/WSFOs, QPB might have provided better guidance had more current rainfall reports been available.

### Recommendation 5.2

NWS should institute a Rainfall Report message to relay rainfall amounts above some threshhold directly to QPB. The Rainfall Report would be analogous to the Storm Report relayed directly to NSSFC in cases of severe local storms. The report should be a ready-to-use format. This would also help other NWS offices, SFSSs, and RFCs. In addition, QPB should receive in real time all rainfall reports relayed via GOES.

# CHAPTER 6

## OPERATIONS AT SAN ANTONIO, AUSTIN, FORT WORTH, AND ABILENE OFFICES

This chapter reviews operations of the San Antonio, Austin, Fort Worth, and Abilene NWS Offices during the period of flash flooding. First, the actions taken by the offices will be reviewed. Attention will be focused primarily on counties with fatalities. Second, observations will be made relative to staffing of the four field offices and to the flash flood program at San Antonio. Third, comments will be offered on procedures used in the issuance of watches and warnings.

One word of explanation before examining the actions taken by NWS offices: the specialized terminology used in reviewing operations first appeared in earlier chapters, with the exception of the term "zone forecast." A forecast zone is a geographic area considered to be relatively uniform weatherwise. The entire country is divided into a series of zones. The zone forecast is used by the media as a "local forecast" for any town within the zone. The Texas forecast zones are shown in figure 6.1. Counties within the zones where deaths occurred are identified. Flash flood watches are normally highlighted in the appropriate zone forecasts in addition to being distributed as separate messages. Warnings are always separate.

### WSFO SAN ANTONIO AND WSO AUSTIN

Severe flooding occurred on both the nights of August 1-2 and 2-3. However, the first night claimed 25 victims in the Hill Country. Everyone was well sensitized to the threat by the second night. As far as can be determined, two deaths occurred about 3 a.m., August 3, in Gillespie County. As discussed in Chapter 1, the deaths were distributed among the counties as follows:

| County | Deaths | NWS Warning Responsibility |
|---|---|---|
| Bandera | 14 | WSFO San Antonio |
| Kerr | 8 | WSFO San Antonio |
| Kendall | 3 | WSFO San Antonio |
| Gillespie | 2 | WSO Austin |
| | 27 | |

Below is a chronology of events. It includes, but is not limited to, the counties with fatalities. In reading through it, keep in mind when and where the deaths occurred. For those not interested in the level of detail

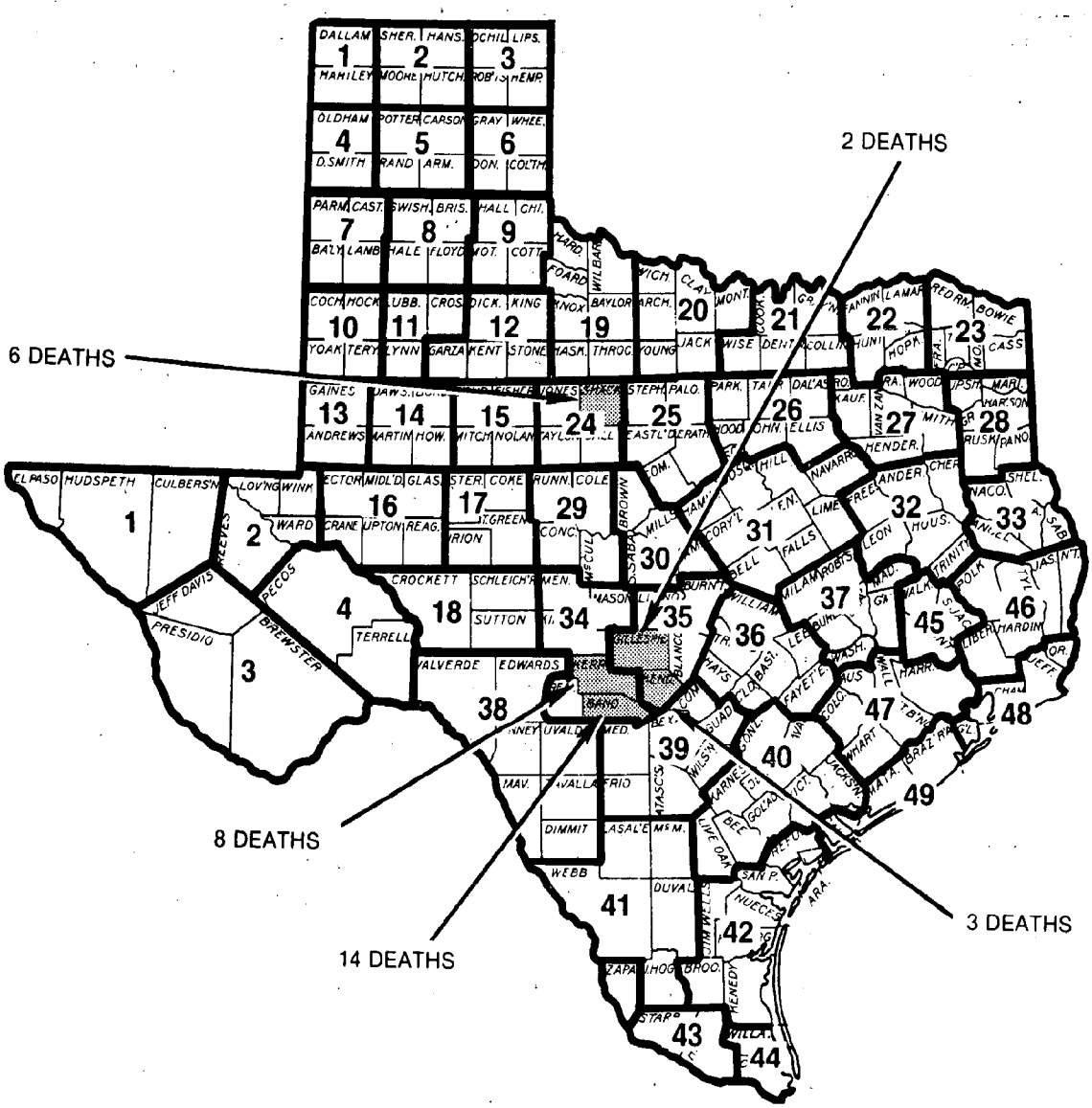



Figure 6.1 -- Texas Forecast Zones.

presented, a brief summary of the important points relative to the counties with fatalities follows the chronology. Unless otherwise stated, all statements refer to actions taken by or information available to the San Antonio office.

## Chronology of WSFO San Antonio and WSO Austin Issuances

### August 1

| Time - CDT | |
|---|---|
| 0840 | Flash Flood Watch for Tuesday morning and afternoon for part of south central and southern Texas, along and 50 miles either side of a line from Laredo to Austin. Over 5 inches of rain had fallen by early morning northeast of San Antonio, with additional heavy rains possible in the watch area. (The worst flooding eventually occurred on the western edge of this watch area.) |
| 0840 | Zone forecasts updated to headline Flash Flood Watch in Zones 35, 36, 39, 41, and eastern 34 and 38. |
| 0930 | First VIP level 4 from Hondo radar close to flood area. (VIP 1 and 2 since 0430). |
| 0930 | San Antonio Special Weather Statement. Heavy rains moving into Bexar County. First caution to the Hill Country counties of Bandera, Kendall, and Kerr for the onset of heavy rain. |
| 1030 | Zone forecasts headlining Flash Flood Watch in same zones as above. |
| 1130 | San Antonio Flash Flood Statement headlining watch and mentioning heavy rain over Southern Bexar, Northern Atascosa, portions of Medina, all of Frio, portions of Uvalde, Real, Bandera, and Kerr Counties. Rainfall amounts of 5 inches mentioned in Northeast Bexar, Comal, Eastern Kerr Counties; 3 inches in Eastern Uvalde County. |
| 1230 | Radar VIP levels drop to 1 and 2 until 1830 in area which later flooded. |

| | |
|---|---|
| 1230 | (Approximate time) Flash Flood Warning Alarm was activated at Kerrville. Notification given to WSFO San Antonio, but apparently not to Kerr County CD. |
| 1255 | San Antonio Flash Flood Warning issued until 1600 for the Guadalupe River in Kerr County. Mentioned rainfall of 4 inches overnight and 2 inches since 0700. (EBS activation requested.) |
| 1300 | Flood Warning for the Upper Guadalupe River. |
| 1400 | Austin Special Weather Statement. Locally heavy showers from San Marcos to Austin. |
| 1450 | Flash Flood Watch through Tuesday night. Extended the first watch and adjusted the area west and northwest. Area was along and 70 miles either side of a line from Eagle Pass to Georgetown, including metropolitan areas of Austin and San Antonio and the Texas Hill Country. Mentioned redevelopment of heavy rain over the Hill Country. (This watch fully enclosed the counties which eventually experienced the most flooding.) |
| 1640 | Zone forecasts headlining Flash Flood Watch in Zones 34, 35, 36, 38, 39, and 41. |
| 1830 | San Antonio Flash Flood Statement continuing watch and specifically mentioning Texas Hill Country in first paragraph. Mentioned rainfall amounts of over 7 inches in the Hill Country since midnight. |
| 1830 | Radar VIP levels begin to increase, first 3 level since morning. |
| 1900 | San Antonio Flash Flood Warning until 2300 for 10 counties: Atascosa, Frio, Medina, Wilson, Guadalupe, Comal, Kendall, Bandera, Kerr, and Bexar. Heavy rain indicated by radar. (No EBS activation request.) |
| 2000 | San Antonio Severe Thunderstorm Warning until 2100 for Atascosa and Bexar Counties. Report of 50-mph wind between Poteet and Pleasanton (about 30 miles south of San Antonio). |
| 2100 | Austin Flash Flood Warning issued until midnight for Gillespie, Blanco, and Hays Counties. Radar shows heavy rain moving into the three counties. (No EBS activation request.) |

2115 Updated zone forecasts continuing Flash Flood Watch through Wednesday morning. Watch headlined in Zones 34, 35, 36, 38, 39, and 41. Locally heavy rains mentioned in the text of zone forecasts.

2130 San Antonio Special Weather Statement concerning the NOAA Weather Radio power failure.

2215 Flood Warning with specific warnings for the Guadalupe from Comfort to Canyon Dam, the Medina below San Antonio, the Sabinal, the Frio, the San Miguel, the Atascosa, the San Antonio, and Cibolo Creek.

2230 Decreased VIP levels on Hondo radar.

2300 San Antonio Flash Flood Statement extending 1900 10-county Flash Flood Warning to 0300 on August 2. Flash Flood Watch continued through Wednesday morning.

2355 Austin Special Weather Statement noting the expiration of the Flash Flood Warning for Gillespie, Blanco, and Hays Counties. Flash Flood Watch continues through the rest of the night.

2400 VIP levels increase on Hondo radar.

August 2

0230 San Antonio Flash Flood Statement to extend Flash Flood Warning for 2 of previous 10 counties: Bandera and Medina to 0600. (Warning expired for other eight counties at 0300.) Mentioned rapidly rising water in Bandera County. Last paragraph of statement modified current Flash Flood Watch area and continued through "today." Modified area was bounded by a line from Cotulla, to College Station, to Victoria, back to Cotulla. The flash flooding was just northwest of the redefined watch area.

0230 Bandera County Sheriff notified about heavy rain to the northwest of Bandera.

0330 Bandera County Sheriff notified of possible flood waters down the Medina River.

0330 Lead Forecaster at WSFO San Antonio called in Principal Assistant for help. He arrived at approximately 0430.

0445 Zone forecasts headlining Flash Flood Watch in Zones 34, 35, 36, 37, 39, and 40. Mention of possible flash flooding in the text of the zone forecasts.

0500 San Antonio Flash Flood Warning for the Sabinal River in Western Bandera County and down river to Uvalde County. Mentioned 7 inches of rain since 11 p.m. Monday, at Vanderpool. Record water levels at Vanderpool. (EBS activation requested.)

0511 Notified radio station WOAI (EBS station) of the warning.

0511 Texas DPS reported a 21-foot rise along the Guadalupe at Comfort and 12 to 14 inches of rain since midnight at Center Point.

0515 San Antonio Flash Flood Warning until 1000 for the Guadalupe and all its tributaries in Kerr and Kendall Counties mentioning above rainfall reports and stating that together with previous heavy rain, "...this will cause extraordinary flash flooding on the river in Kerr and Kendall Counties." An urgent request was made for people to get away from the river, especially in the towns of Hunt, Ingram, and Kerrville. "...very serious flash flooding will be moving down the Guadalupe through Kerr and Kendall Counties." (EBS activation.)

0525 The Kerr County Sheriff was called to be sure he had heard the warning. He reported that a house had been washed away at Hunt.

0525 The Kerrville Fire Department (County CD) was called to tell them of urgent need to get people away from the river.

0530 Calls made to WOAI (EBS station), Kerrville Police, and Kendall County Sheriff to make sure they had warning.

0545 Called radio station KERV in Kerrville. Warning broadcast live, urging everyone to get away from the river.

0600 San Antonio Flash Flood Warning to extend earlier warning to 1100 in Bandera and Medina Counties. Mentioned rapidly rising water along Hondo Creek in Medina County and 7 to 14 inches of rain in Bandera County. (EBS activation requested.)

0645 Flood Warning for the Upper Guadalupe, Upper Medina, and Sabinal Rivers. Included specific rainfall and damage reports from each basin as well as information on small streams in Bandera, Medina, Real, Kerr, Kendall, and Uvalde Counties.

0700 Austin Flash Flood Warning issued until noon for Gillespie and Blanco Counties. Heavy rain indicated by radar and reported by observers at Stonewall and Fredericksburg in Gillespie County. Flood waters moving down the Pedernales toward Johnson City. (EBS activation requested.)

0810 San Antonio Flash Flood Warning until 1300 for the Frio River in Real and Uvalde Counties, specifically mentioning the Garner State Park area. Rainfall reports of 7 to 10 inches included. People urged to seek higher ground. (EBS activation requested. Texas DPS apparently unable to answer on warning notification.)

0823 Called Garner State Park with warning.

0930 Sharp decrease in radar VIP levels at Hondo WSMO.

0930 WSFO San Antonio issued river forecasts and rainfall report, including daily reports.

1000 San Antonio Flash Flood Warning until 1500 for Kerr, Kendall, Bandera, Medina, Real, and Uvalde Counties. This warning extended and consolidated three current warnings for the six counties. Specific mention of the Guadalupe, Medina, Sabinal, and Frio Rivers, and Hondo Creek. (EBS activation requested.)

1030 Zone forecasts headlining Flash Flood Watch in Zones 36, 39, 35, and 34, but dropping it in Zones 37 and 40. Flash Flood Warning headlined in Zones 34, 35, 38, and 39.

1615 Revised Flood Warning for the Medina and San Antonio Rivers.

1645 Zone forecasts headlining flood warnings for rivers and streams in Zones 34 and 35.

1645 Flash Flood Watch no longer in effect.

| | |
|---|---|
| 1700 | Most radar VIP levels drop to zero over the flood area. |
| 1830 | San Antonio Severe Weather Statement on small area of thunderstorms moving into San Antonio. Mentioned locally heavy rain, lightning, and gusty winds. |
| 1930 | Radar VIP levels pick up again. |
| 1945 | San Antonio Flash Flood Warning until midnight for Comal, Kendall, Kerr, Bandera, and Northern Bexar Counties. Mentioned Cibolo Creek, Guadalupe and Medina Rivers in the Hill Country. (No EBS activation request.) |
| 2100 | San Antonio Special Weather Statement summarizing rainfall and flood information from the previous day. |
| 2200 | San Antonio Flash Flood Statement cancelling the warning for Comal and Northern Bexar Counties, but holding it in effect for Kerr, Kendall, and Bandera, and specifically mentioning Garner State Park. |
| 2230 | San Antonio Severe Thunderstorm Warning until 2330 for Zavala and Dimmit Counties based on radar information. |
| 2300 | Flash Flood Watch issued for the Texas Hill Country for the rest of Wednesday night and Thursday morning. Up to 4 inches or more of rain possible from redevelopment. |
| 2300 | Updated zone forecasts headlining the watch and mentioning locally heavy rain in Zones 34 and 35. |
| 2330 | Updated flood forecast issued for the Guadalupe and San Antonio Rivers. |
| 2400 | San Antonio Flash Flood Warning until 0400 for Kendall, Kerr, Bandera, and Real Counties, based on radar information. (Continuous VIP 4 or 5 in a few grids over the specified counties.) (No EBS activation request.) |

August 3

Time - CDT

| | |
|---|---|
| 0045 | San Antonio Special Weather Statement. Guadalupe River within 1 inch of the bridge on U.S. Highway 281 north. |

| | |
|---|---|
| 0100 | San Antonio Special Weather Statement. Water lapping over the bridge on Highway 281 north. |
| 0115 | San Antonio Special Weather Statement. Specific information on river levels as reported by the Texas Department of Public Safety. |
| 0130 | Updated flood warning for the Guadalupe River downstream to Comfort. |
| 0315 | San Antonio Flash Flood Warning until 0900 for Kendall, Kerr, Bandera, and Real Counties. Rainfall reports included. People urged to stay out of lowlands and away from rivers and creeks. |
| 0445 | Zone forecasts headlining watch in Zones 34, 35, 36, and 39. |
| 0600 | Flood Statement for the Guadalupe River. |
| 0600 | Radar VIP levels drop. |
| 1030 | Flash Flood Watch issued to extend current watch through Thursday night. Specific counties named, covering forecast Zones 34 and 35 only. Mentioned threat of additional heavy rain. |
| 1040 | Updated zone forecasts headlining the watch in Zones 34 and 35 and mentioning the chance of flash flooding. |
| 1430 | San Antonio Flash Flood Statement continuing the watch. Mentioned that rain had tapered off in the watch area, but a threat of heavy rain existed later. |
| 1645 | Zone forecasts headlining the Flash Flood Watch in Zones 34 and 35. Chance of heavy rain included in the text. |
| 1730 | San Antonio Flash Flood Statement. No significant rainfall in the watch area during the afternoon; however, the approach of a cool front should increase the threat of additional rain in the watch area. |
| 2130 | San Antonio Flash Flood Statement extending watch through Friday morning. No significant rainfall in the watch area during the afternoon or evening, but additional rain still expected with the approach of the cool front. |

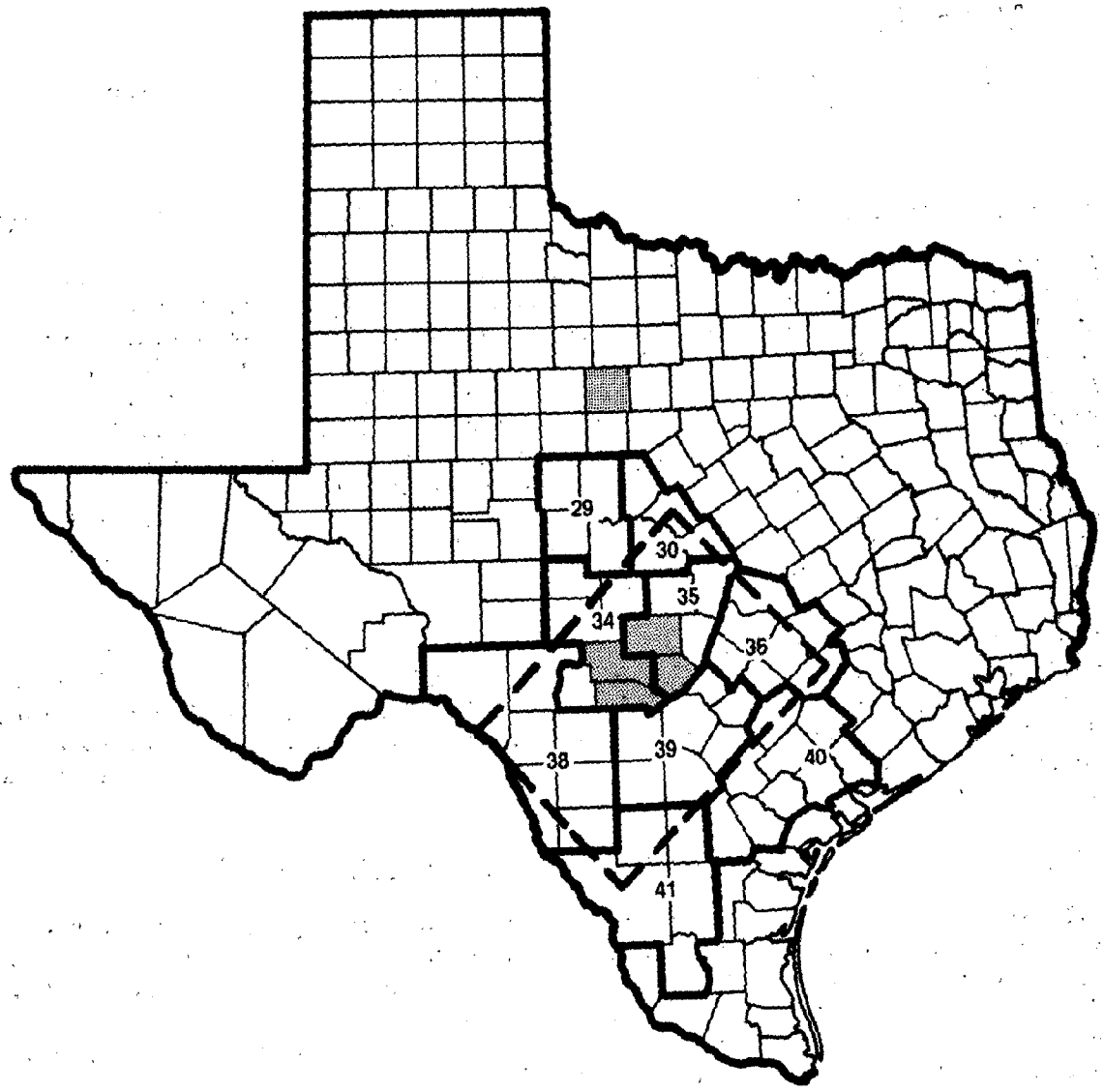



Figure 6.2 -- Flash Flood Watch Area Issued by WSFO San Antonio at 2:50 p.m. CDT August 1.

August 4

Time - CDT

0430 San Antonio Flash Flood Statement to end the current watch.

Summary of Critical Actions by WSFO San Antonio for Counties with Fatalities

The first Flash Flood Watch was issued at 8:40 a.m., August 1, for a large area east of the locations which had fatalities early the next morning. At about 12:30 p.m., the Kerrville/Guadalupe River Flash Flood Alarm sounded in Kerrville. When informed, the WSFO issued a Flash Flood Warning (at 12:55 p.m.) for Kerr County, followed by a Flood Warning (at 1 p.m.). A second Watch, issued at 2:50 p.m., continued at 6:30 p.m., completely enclosed the counties that had fatalities some 12 to 15 hours later. A Flash Flood Warning specific to 10 counties, including Kendall, Kerr, and Bandera, was issued at 7:00 p.m. CDT. The warning for Kerr and Kendall Counties expired at 3:00 a.m. CDT, August 2, but was reissued at 5:15 a.m. CDT.

The staff kept on top of the situation and disseminated 41 issuances until the flooding abated on August 3. The media and public officials were well supplied with material. Considering the information available to them, WSFO San Antonio did a very fine job with its releases to the press so as to emphasize the seriousness of the situation. (See Appendix A for selected actual issuances.)

Summary of Critical Actions by WSO Austin for Gillespie County

Gillespie County was placed under a Flash Flood Watch by WSFO San Antonio at 2:50 p.m., August 1. At 9:00 p.m., based on radar reports of heavy rain moving north, WSO Austin issued a Flash Flood Warning for Gillespie County. This Warning expired at midnight but the Watch continued. Based on new reports of heavy rain, another warning was issued at 7 a.m., August 2. (See Appendix A for warning.) This was valid until noon.

Unfortunately, a truck carrying two men was washed off a low area of a highway early on August 3, well after flash flooding had occurred. WSO Austin did a creditable job with the information available during the flash flooding.

WSFO FORT WORTH AND WSO ABILENE

All six flood victims in Albany died on the evening of August 3. The only reported times of death were after 7 p.m. Below is a chronology of events

recorded at the two offices during the flash flooding in the Big Country. It included, but is not limited to, the Albany situation. Keep in mind when and where the deaths occurred and that teletypewriter communications from WSO Abilene were lost. For those not interested in the level of detail presented, a brief summary of the important points relative to Albany follows the chronology. Where not otherwise stated, all statements refer to actions taken by the WSFO Fort Worth.

Chronology of WSFO Fort Worth and WSO Abilene Issuances

August 2

| Time - CDT | |
|---|---|
| 1020 | Zone forecasts headline Flash Flood Watch for Wednesday night in Zones 25-26-29-30-31. |
| 1115 | Flash Flood Watch for Wednesday night for parts of North Central Texas (most of Zones 25-26-29-30-31). "Remnants of Tropical Depression Amelia could produce up to six inches of rain." |
| 1600 | Fort Worth Special Weather Statement continuing the Flash Flood Watch for Wednesday night for most of the original area, except that Coleman, Eastland, and Falls Counties and parts of other counties were deleted from the original area. |
| 1640 | Zone forecasts headline Flash Flood Watch for Wednesday night in Zones 25-26-29-30-31. |
| 1800 | Updated zone forecasts headlining Flash Flood Watch continuing for late Wednesday night and Thursday in Zones 25-26-29-30-31. |
| 2000 | Fort Worth Special Weather Statement cancelling the Flash Flood Watch because of less than anticipated rainfall amounts, but adding that a flash flood watch may be necessary again Thursday afternoon. |

August 3

| Time - CDT | |
|---|---|
| 0225 | Abilene Special Weather Statement continuing the Flash Flood Watch for parts of North Central Texas for the rest |

of the night, including Brown and Coleman Counties. The Fort Worth statement at 2000 the preceding evening had cancelled the watch, however.

0440 Zone forecasts headlining Flash Flood Watch for Thursday and Thursday night in Zones 25-26-29-30-31. Mentioned possible heavy rain up to 6 inches.

0500 WSMO Stephenville informed WSFO Fort Worth that the radar D/RADEX was inoperative.

0800 Fort Worth Special Weather Statement continuing the Flash Flood Watch for Thursday and Thursday night, but redefining the area, effectively dropping the watch in most of Zone 29, and half of Zones 25 and 31. The statement included some specific rainfall amounts, including 6.9 inches near Scranton in Eastland County and 6.2 inches at Coleman in Coleman County, both in 24 hours.

0850 Abilene Special Weather Statement mentioning flooding in West Abilene and stating that a flash flood warning may be required later in the day (Abilene is in Taylor County.)

0900 Flash Flood Warning from Abilene for "today and tonight" for Coleman and Brown Counties. "Six to eight inch rains during the night have produced a sharp rise on Pecan Bayou." (No EBS activation request.)

0915 Abilene Flash Flood Warning "...for Taylor County today. Little Elm Creek was running one foot over banks at 8:30 a.m. and heavy rain is continuing. Persons are advised to be watchful along Little Elm Creek and be prepared to move to a place of safety if the need arises. Persons along other creeks and along low lying areas should also be aware that conditions may worsen as the day progresses."

1030 Fort Worth Special Weather Statement that shifted the Flash Flood Watch in North Texas to the Wichita Falls/ Abilene area for this afternoon and tonight. The new watch area was "west of a line through Wichita Falls, Eastland, Brownwood, and Junction. Up to six inches additional rain may fall in the Big Country area around Abilene this afternoon and tonight. The expected rains will be sufficient to cause flash flooding to occur."

1030 Zone forecasts headlining Flash Flood Watch in Zones 19-20-24-25-29. Mentioned heavy rain up to 6 inches.

1220 Fort Worth River Flood Bulletin giving crest forecasts for the Colorado and San Saba Rivers and the Elm Creek.

1600 Fort Worth Special Weather Statement continuing Flash Flood Watch for Thursday night. Up to 4 inches of new rain possible in the watch area Thursday night. "Storms are expected to increase in strength and number tonight. Conditions are such there is a high potential for flash flooding."

1630 Abilene Flood Statement continuing a Flash Flood Warning for Taylor, Brown, and Coleman Counties tonight. Elm Creek above flood stage south of Abilene and continuing to rise.

1635 Fort Worth Flood Bulletin with additional crest forecasts for the Colorado River.

1640 Zone forecasts headlining Flash Flood Watch in Zones 19-20-24-25-29. Rain likely accumulating up to 4 inches tonight.

1715 Abilene and vicinity forecast headlining Flash Flood Warning tonight through Friday morning.

1940 Abilene Flood Statement continuing a flood warning for Taylor, Brown, and Coleman Counties through Friday morning. Specific flooding information for Lytle, Cedar, and Elm Creeks.

1955 Abilene Flood Statement continuing a flood warning for Taylor, Brown, and Coleman Counties through Friday morning.

2040 Abilene Flash Flood Warning for Shackelford County (including the Albany area) until midnight. Flash flooding reported by the Texas Department of Public Safety at 8:40 p.m. The warning was broadcast over NOAA Weather Radio at 2040, but delayed until 2053 on Weather Wire because of the teletypewriter outage at WSO Abilene. (EBS Activation requested.)

2120 Abilene Flood Statement continuing the flood warning for Taylor, Brown, and Coleman Counties through Friday morning and the Flash Flood Warning for Shackelford County until midnight. Specific mention of flooding reports.

| | |
|---|---|
| 2125 | Abilene Flash Flood Warning through Friday morning for Jones, Shackelford, and Haskell Counties. Heavy rain indicated by radar. (EBS activation requested.) |
| 2255 | Abilene Flash Flood Statement continuing Flash Flood Warnings for Jones, Shackelford, Haskell, Taylor, Brown, and Coleman Counties through Friday morning. Heavy rain continuing: 9 inches at Stamford and 11 at Ericksdahl (north of Abilene). |

August 4

Time - CDT

| | |
|---|---|
| 0215 | Abilene Flash Flood Warning until noon for Throckmorton County. Rainfall in excess of 17 inches upstream on creeks that drain into Throckmorton County. Persons in low-lying areas should be prepared to evacuate. (EBS activation requested.) |
| 0315 | Abilene Flash Flood Warning until noon for Callahan County. Flooding reported by Texas Department of Public Safety on Highway 36. (EBS activation requested.) |
| 0440 | Zone forecasts headlining Flash Flood Watch for today in Zones 19-20-24-29. Headline of local flash flood warnings in effect in Zones 24 and 29. Rains to near 4 inches mentioned in all four zones. |
| 0645 | Fort Worth Flash Flood Warning until 1100 for Stephens County. Heavy rain indicated by radar in the western part of the county with little or no movement. (EBS activation requested.) |
| 0800 | Fort Worth Flash Flood Statement. Flash Flood Warnings in effect into the forenoon for portions of north Texas along a Wichita Falls, Brownwood line westward to near an Abilene, Childress line. The area as described in the statement does not agree with the warnings in effect. |
| 0815 | Fort Worth River Flood Bulletin for the Brazos River stating that the expected sharp rise will crest near the record flood level at Fort Griffin. |
| 0820 | Correction of the 0800 Flash Flood Statement. |

| | |
|---|---|
| 1030 | Zone forecasts headlining Flash Flood Watch for the afternoon in Zones 19-20-24-25-29-30. Rains up to 4 inches possible during the afternoon. |
| 1050 | Fort Worth Severe Weather Statement continuing the Flash Flood Watch west of the Wichita Falls/Eastland/ Brownwood/Junction line. Mentioned specific rainfall and flooding reports, including the reported deaths at Albany. |
| 1050 | Abilene Flash Flood Statement. Flash Flood Watch continues. Flash Flood Warning continues until noon for Taylor, Jones, Haskell, Throckmorton, Callahan, and Shackelford Counties. The warning for Coleman and Brown Counties was cancelled. Specific information on flooding. |
| 1200 | River Flood Bulletin from Fort Worth for the Colorado and Brazos Rivers. Crest forecasts given for specific forecast points. |
| 1310 | Abilene Flash Flood Statement continuing the watch and stating that the flash flood warnings have been extended through the afternoon for Taylor, Jones, Haskell, Throckmorton, Callahan, and Shackelford Counties. The warnings had expired at noon. Other specific information on flooding and damage included. |
| 1330 | Abilene Flash Flood Statement concerning Lake Throckmorton and possible dam failure. |
| 1515 | Abilene Flash Flood Warning through Saturday morning (August 5) for Coleman County with detailed rainfall and flooding information. (EBS activation requested.) |
| 1640 | Zone forecasts dropping the Flash Flood Watch. |
| 1815 | Flash Flood Warning from Abilene until Saturday morning for Taylor, Jones, Haskell, Shackelford, and Throckmorton Counties, and cancelling the earlier warning for Coleman County. (EBS activation requested.) |
| 1950 | Abilene Flash Flood Statement continuing the Flash Flood Warning for Taylor, Jones, Haskell, Shackelford, and Throckmorton Counties through Saturday morning, and mentioning a break in Lake McCarty Dam near Albany. |

2100 Fort Worth Flood Warning for the Upper Brazos River stating that a record flood rise was moving down the river.

2330 Abilene Flash Flood Statement continuing warnings for Taylor, Jones, Haskell, Shackelford, and Throckmorton Counties through Saturday morning. Rain has ended, but heavy runoff still occurring. Specific flooding reports included.

Summary of Critical Actions by WSFO Fort Worth for Shackelford County

At 10:30 a.m. on August 3, a Special Weather Statement shifted the watch issued in earlier zone forecasts for "today and tonight" to the Albany area. This lead the disastrous Albany flood event by some 8 or 9 hours. This condition was further highlighted in zone forecasts issued at 10:30 a.m. and 4:40 p.m. and further reinforced by another Special Weather Statement issued at 4 p.m. which continued the Flash Flood Watch for Thursday night. This statement emphasized an expected increase in strength and number of storms during the night and that conditions held high potential for flash flooding. (See Appendix A for the statement issued.)

Summary of Critical Actions by WSO Abilene for County with Fatalities

WSO Abilene began a series of statements and warnings for parts of its warning area at 8:50 a.m., Thursday morning, August 3. The first warning specifically for Albany and Shackelford County was issued at 8:40 p.m. after the Department of Public Safety informed the WSO that flooding was occurring. The zone forecast that the media would have used for Shackelford County and the Abilene local forecast had both carried the Flash Flood Watch headline since early Thursday morning.

ADDITIONAL COMMENTS ON THE FOUR FIELD OFFICES INVOLVED

Two topics will be covered--staffing of the four offices and the outstanding flash flood program of the San Antonio office. First, staffing. WSFO San Antonio: Shifts prior to the flooding were staffed at normal levels until the Lead Forecaster working the midnight shift on the morning of August 2 called in the Principal Assistant at 3:30 a.m. CDT. Staffing returned to normal late in the day except for the many extra hours which the Service Hydrologist spent monitoring rainfall reports and river stages and issuing flood warnings and statements. However, the Lead Forecasters working the evening and midnight shifts both expressed a need for extra help to answer numerous telephone inquiries from the media and from individuals who had acquired the office's unlisted telephone numbers from the media and other sources. The Lead Forecaster on duty the evening

of August 2 was reluctant to call the Principal Assistant again since he had already been called in at 3:30 a.m. that morning and had worked several hours thereafter.

WSO Austin: Only one county in the Austin area of responsibility--Gillespie--experienced exceptionally heavy rains. WSO Austin issued several flash flood warnings and statements pertaining to the area. Austin WSO had no special problems. It was necessary to hold over one employee, whose normal tour of duty would have ended at midnight, until 6 a.m. the next morning to handle the increased workload.

WSFO Fort Worth: Shifts were staffed at normal levels during the flooding on August 3. However, the forecasters on duty that evening were exceptionally busy. As in San Antonio, there were numerous telephone inquiries from the public on unlisted numbers. The staff at Fort Worth was also responsible for typing and transmitting teletypewriter messages relayed by telephone from WSO Abilene during the teletypewriter outage at that office.

WSO Abilene: The events of August 3 placed an extreme burden on this small office. Of the authorized weather service specialist complement of 6 (including the Official in Charge), personnel were scheduled so there would be three on duty at all times throughout the flood event. Beginning with the early morning hours of August 2 and continuing into the morning of August 5, Abilene was heavily involved in preparing and disseminating flash flood warnings and statements for most of their 13-county area, coordinating with adjacent NWS offices, soliciting rainfall and flooding reports, and acting as advisors to public safety officials, in addition to conducting the normal program of surface weather observations, NOAA Weather Radio and public service. Demands on station personnel were further compounded by the need to backup the Stephenville office when its radar went out of service. Earlier, the loss of all teletypewriter communications required the staff to telephone weather and flood issuances to Fort Worth WSFO for entry on the NOAA Weather Wire.

Some WSFO lead forecasters were reluctant to request extra help even though it is NWS and Southern Region policy to encourage overtime in warning situations. While it cannot be categorically stated that the lack of overtime help made a difference in the quality and timeliness of NWS watches and warnings, additional staffing would have significantly reduced fatigue and would have permitted closer coordination among the offices involved and with the SFSS at Kansas City and with NMC.

Now to the outstanding flash flood program of the San Antonio office. This office over the years has been deeply concerned with the continuing problem of flash flooding in its area. It has translated this concern into a very active effort to keep itself and the community prepared. The Meteorologist in Charge is fully behind the flash flood program. This support is carried

through the Principal Assistant, the Service Hydrologist, and the Disaster Preparedness Meteorologist who implement flash flood procedures. Everyone in the office is flash flood conscious. Within their limited resources they have actively encouraged local communities to be flash flood conscious. The WSFO also has maintained a close working relationship with the media, many local communities, and the Fort Worth RFC.

## COMMENTS ON PROCEDURES

During the flash flood events of August 1-4, several flash flood watches were adjusted (extended in time or altered in area) and flash flood warnings were extended through the use of flash flood and special weather statements. Although the NWS Operations Manual does not specifically include these types of adjustments in the uses of flash flood statements, it does show an example of a flash flood statement extending a warning beyond the existing valid time, thus indirectly suggesting the use of flash flood statements for such adjustments.

In several instances WSFO Fort Worth headlined a Flash Flood Watch in zone forecasts when an actual Flash Flood Watch had not been issued. Both forecast offices occasionally added or dropped the watch headline for specific forecast zones even though no change in the watch area had been made. One Special Weather Statement issued by WSO Abilene headlined the continuation of a Flash Flood Watch that had been cancelled earlier by WSFO Fort Worth. There were also statements issued by WSFO Fort Worth that used different terminology to describe watch areas previously defined by forecast zones, effectively changing the watch area and causing inconsistencies between the redescribed area and the zones headlined. Several statements issued by WSO Abilene interchanged the phrases "flash flood warning" and "flood warning."

Since most products issued by the San Antonio, Austin, Fort Worth, and Abilene offices were timely and well written, the above inconsistencies and variations probably were of little consequence. Note that the Flash Flood Watch headline was included in forecasts for both the Hill Country and the Albany area for many hours (including local TV news time) prior to each flood event.

## FINDINGS AND RECOMMENDATIONS

### Finding 6.1

The San Antonio WSFO staff performed outstandingly in issuing timely, lucid, and effective flash flood watches and warnings. The Hondo radar station put forth a best effort to provide the WSFO with extremely important, pertinent radar information in the face of some technical difficulties with radar frequency stability. The Abilene WSO, with

unprecedented requirements for data collection, evaluation, and issuance of flood warnings plus regularly assigned duties, performed in the best of Weather Service traditions over the 3-day episode. The authorized six-person staff was scheduled for maximum utilization of talent though this required many hours of overtime with only short rest periods for some before returning to duty.

Recommendation 6.1

Appropriate commendations should be awarded.

Finding 6.2

The San Antonio office has an outstanding flash flood program.

Recommendation 6.2

The San Antonio flash flood program should be brought to the attention of all appropriate WSFOs. The Flash Flood II Videotape is an effective means.

Finding 6.3

Although it did not affect our services some WSFO forecasters were reluctant to ask for overtime help. This was not a problem at the small WSOs which must use frequent overtime.

Recommendation 6.3

NWS should re-state its policy of using overtime as needed to meet the exigencies of severe weather and flooding situations and that the decision must be made at the local level. At WSFOs the Lead Forecaster, in the absence of the MIC or a PA, must exercise this judgment.

Finding 6.4

Abilene, like most WSOs, is minimally staffed to perform its mission. The staff worked extremely long hours under great pressures to meet service needs of the community.

Recommendation 6.4

Minimum staffing at WSOs should match staffing standards. A minimum staff of eight is called for at 24-hour WSOs with surface observations, local warning radar, and one NOAA Weather Radio (NWR).

Finding 6.5

Several watches and warnings were adjusted or extended through statements. This is not the most effective way to get attention of the media and public officials.

Recommendation 6.5

The Operations Manual should be brought up to date to include specific instructions on hydrologic service functions and methods, including Flash Flood Watches and Warnings. The methods should be analogous to those for severe local storms. New Flash Flood Watches and Warnings should be required to extend valid time periods or to include areas not already contained in a current watch or warning area. This procedure would promote full dissemination of the new area or valid time by including the terms "watch" or "warning" in the heading and by including the codes necessary to activate alarms on appropriate teletype circuits. Flash Flood Statements should be used only to remove parts of the areas covered by a watch or warning, to terminate the watch or warning, and to provide pertinent information on current watches and warnings.

Finding 6.6

There were procedural problems relating to watches issued at WSFOs Fort Worth and San Antonio. These problems could be important in some storm situations.

Recommendation 6.6

NWS Southern Region should ensure that office staffs are fully cognizant of proper watch procedures.

CHAPTER 7

# WARNING DISSEMINATION, COMMUNITY DISASTER PREPAREDNESS, AND PUBLIC RESPONSE

This chapter addresses warning dissemination, community disaster preparedness, and public response in that order. Each represents a critical element in the total warning process.

## WARNING DISSEMINATION

Principal channels for sending weather and flood warning information to the public are via the direct-to-user NOAA Weather Radio (NWR) system and the NOAA Weather Wire Service (NWWS). The NWWS provides simultaneous, direct, hard copy to radio and television stations and many public safety offices. Associated Press (AP) and United Press International (UPI) are subscribers to the Weather Wire and depend upon it for Weather Service Information that is further disseminated to new wire subscribers. The National Warning System (NAWAS), a voice circuit, interconnects key points of the Texas Department of Public Safety and all National Weather Service Offices in Texas. The Weather Service has access to this NAWAS circuit for information exchange on warning or possible warning situations.

### o NOAA Weather Radio (NWR)

NOAA Weather Radio provides continuous, around-the-clock broadcasts of the latest weather information directly from National Weather Service offices. During severe weather, National Weather Service personnel interrupt the routine recorded weather broadcasts with warning messages. They can also activate specially designed warning receivers. Such receivers either sound an alarm indicating an emergency exists, alerting the listener to turn the receiver up to an audible volume; or, when operated in a muted mode, automatically increase the volume so the warning message is heard. Warning alarm receivers are especially valuable for schools, hospitals, public-safety agencies, and news media offices.

NOAA Weather Radio transmissions from WSFO San Antonio reach into the extreme eastern part of Bandera County, the extreme southeastern part of Kerr County, and the southern half of Kendall County, but do not cover the area hard hit by the flash floods. The San Antonio NWR had been knocked off the air by lightning at about 9:15 p.m. on August 1. The station returned to the air at about 11 p.m. While the station was operating, all watches, warnings, and statements that were broadcast were done so quickly. Flash flood safety messages were aired frequently over NWR.

Abilene's NOAA Weather Radio continued to operate throughout the flooding episode. The Abilene staff gave heavy emphasis to the flood situation in determining programming, immediately broadcast numerous advisories, and repeatedly aired the flash flood safety rules. Some broadcasts were made live, because of the exigencies of the situation. The NWR is tied in with a locally developed emergency broadcast system (as distinguished from the National EBS program). This provides a direct audio feed from the NWR audio console via telephone line to Radio KRBC and several other Abilene radio stations to ensure that, should the NWR transmitter go off the air, a backup exists for getting the information into the commercial broadcast system. This feature is activated on demand. Radio KRBC's signal is clearly heard at Albany. NWR reception is marginal to ineffective within the town of Albany, largely because the town lies several hundred feet below nearby hills to the southwest and west.

Under the current national plan for NWR, there are no additional transmitters planned for Texas.

o NOAA Weather Wire Service (NWWS)

This teletypewriter channel, which provides hard copy of all warning information is intended primarily to serve the media, is available to anyone who wishes to pay for the teletypewriter equipment rental and local line charges. Many radio and television stations serving the San Antonio-Hill Country areas and the Albany area subscribe. Broadcasters interviewed indicated they were happy with the service. Complete NWWS in Texas costs about $90 per month. Approximately 260 television, radio, and cable TV outlets in Texas subscribe to the Weather Wire Service.

Other radio and television stations in the area rely on the AP and UPI wire services to relay NWS watches, warnings, and statements from NWWS. However, this relay often introduces significant delays versus direct NWWS receipt.

All teletypewriter communications at Abilene WSO were lost around 9 a.m. of August 3 as water leaked through the roof of the building. Fortunately, the FTS telephone line remained in operation and it was then held open continuously for communication with WSFO and RFC Fort Worth. WSO Abilene used this voice channel to read all releases that normally would have been entered there on NWWS, to WSFO Fort Worth for entry on the North Texas circuit. This procedure introduced short delays, although not significant, with respect to warning effectiveness. As releases were drafted by WSO Abilene, they were read to Fort Worth as another employee aired them over NOAA Weather Radio.

o National Warning System (NAWAS)

This telephone hotline system operated nationally by the Defense Civil Preparedness Agency (DCPA) is quite effective in disseminating warning information to local officials and in supplying feedback of storm reports to NWS warning offices. Figure 7.1 shows the location of Texas NAWAS drops. All NWS warning offices, including San Antonio and Abilene and all NWS network radar offices in Texas, have NAWAS drops. In addition, drops are also located at 33 Department of Public Safety (DPS) offices, including Abilene, San Antonio, and Kerrville.

WSFO San Antonio used the NAWAS nearly a dozen times to distribute flash flood and severe thunderstorm watch and warning messages to Texas Department of Public Safety offices and other points. In the Abilene area, heavy traffic load on NAWAS, particularly communications relating to rescue and disaster relief, inhibited WSO Abilene's use of NAWAS, but did not detract significantly from their operational effectiveness as alternate communications were used.

At 5:48 a.m. CDT, on August 2, the NAWAS failed at the Kerrville DPS office. As we know it, this coincided with the failure of nearly all telephone communications in the area. The system was returned to normal operation at 5:17 p.m. on August 2.

o Telephone

Telephone service in parts of Kerr, Kendall, and Bandera Counties was lost during the early morning hours of August 2. However, massive telephone outages did not occur until about 5:45 a.m. The phones went dead while the San Antonio WSFO was talking with KERV-radio (Kerrville). There was also a major disruption of telephone service in the Albany area.

Although dissemination checklists used by WSFO San Antonio and WSO Abilene require some telephone calls to key persons and public safety organizations, most dissemination is accomplished by NAWAS, NWR, NWWS, and by local fan-out procedures. One such fan-out system involved the Texas State Park system. One call to the State Park Headquarters in Austin (manned 24 hours/day) results in notification to any affected county game warden via either of two radio systems. However, the warning will not necessarily be relayed to State Park offices unless the game warden telephones it.

Dissemination by public officials via local warning call lists is at the discretion of the local authorities. There was some indication that fan-out within communities and among adjacent communities was not as effective as it could have been. At Abilene, all telephone communications circuits

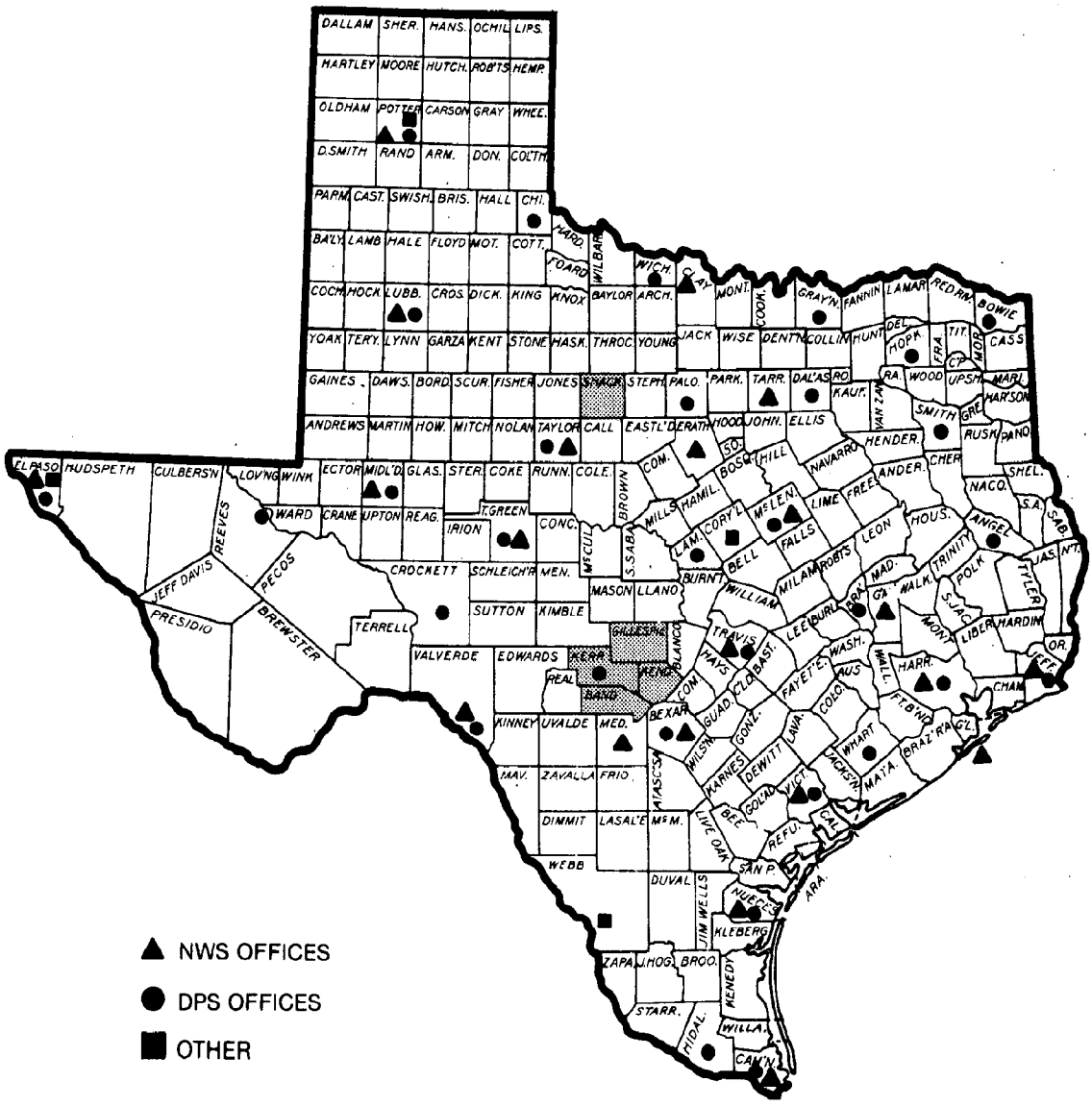



Figure 7.1 -- Texas NAWAS Terminals.

remained in service at the WSO. As an emergency measure, the normal "ring-through" feature on the public telephone was disabled to provide an additional line for communication with public safety officials.

o Mass Media Dissemination

Kerr, Kendall, and Bandera Counties are served principally by San Antonio radio and TV stations. There are one radio station (KERV) and one cable television system in Kerrville. The media did an excellent job of passing on information from the San Antonio office. Most San Antonio radio stations with which we spoke had highlighted the flash flood watches and warnings in their hourly news broadcasts, while some television stations used visual "crawls" to periodically inform their viewers of flood threats.

Both KERV and the Kerrville cable system stayed on the air during much of their normal off-the-air time. KERV shut down for a short period just after midnight on August 2, but resumed broadcasting immediately after receiving a call from the Kerrville police chief requesting such action. KERV has NWWS and was in contact with NWS and local offices during the morning of August 2. According to people we interviewed, KERV frequently broadcast NWS bulletins verbatim and repeated the information several times for emphasis and completeness.

The flash flood that struck Albany occurred during daylight hours when all radio and television stations serving that area were on the air. Radio Station KDWT, Stamford, devoted the major portion of its programming to airing current weather and rainfall reports, flash flood safety rules, road and river reports, and rescue operations. KDWT remained on the air most of the night, well beyond its normal shutdown time, to continue to serve the area. KDWT is heard in Albany and is listened to extensively in the Stamford-Haskell area.

To speed the distribution of warnings, broadcasters in many areas voluntarily take part in the Emergency Broadcast System (EBS). About 2 years ago, an agreement between the Federal Communications Commission, the Defense Civil Preparedness Agency, and the National Weather Service was reached to revitalize the Nation's Emergency Broadcast System. This agreement stressed its use for short-fuse weather warnings. A key element in this effort was the holding of State seminars and workshops to develop specific written plans and procedures for use of EBS. Final plans and revised procedures have not yet been written for Texas, although EBS key stations exist in the State with procedures generally set up for national but not for State and local emergencies. Seminars have been held in all States (including Texas), and 12 States have completed their written plans. Plans have also been written for approximately half of the Nation's 560 EBS operational areas.

A request to activate the EBS was included in more than half the flash flood warnings issued by WSFO San Antonio and all but one flash flood warning issued by WSO Abilene. EBS was not used in the San Antonio area, as the media apparently felt its use should be limited to nuclear attack. EBS was, however, used effectively in the Abilene area.
There is excellent cooperation between the NWS and the central Texas media. This is perhaps most clearly exemplified by the following excerpt from a KTSA/KTFM radio (San Antonio) broadcast, some 12 hours before the extraordinary flash flooding occurred in Kerr, Kendall, and Bandera Counties;

> "...I would like to pause here to thank the Federal Employees that had a hectic afternoon at the National Weather Service, but still took time to give KTSA/KTFM information to relay to our Texas listeners...especially hydrologist George Kush whose job is watching the river gages."

After the flooding, KTSA broadcast an editorial that concluded with:

> "To end these reflections on a positive note, an expression of gratitude to the National Weather Service for its tireless, and invaluable information before and during the storm crisis."

This relationship enhanced the dissemination of official flash flood information. We estimate that about half of the people in the flooded areas were aware of the flash flood threat because of information distributed primarily by the mass media.

o Law Enforcement and Other Communications

The Texas Department of Public Safety's Law Enforcement Teletypewriter System (TLETS) is used by the DPS to distribute NWS warnings across the State as they deem appropriate. This network is a high-speed, partially computer-driven teletypewriter communications system reaching into nearly every law enforcement and State police office in the State. A control point in Austin takes NWS warnings from the NWWS (paper tape), then manually inserts the tape into the TLETS. Local DPS offices have backup phone lists for law enforcement offices without TLETS. During the period August 1-3, WSFO San Antonio warnings were transmitted over this network and were received by the Kerrville police and the Kerrville DPS offices. Most releases were transmitted within minutes, but a few were delayed by as much as 30 minutes.

At around 5:45 a.m. on August 2, some police and fire communications systems failed in the Kerrville area. This was about the same time the phone system in the area went dead.

WSFO San Antonio has in the office a VHF transceiver allowing direct communications with Department of Public Safety; Civil Defense; local, city, and county public safety offices; and local American Red Cross. This communications link was available and used as needed in the flooding emergency.

o Private Citizen Communications

According to several officials interviewed in Kerr, Kendall, and Bandera Counties, amateur radio and, to a lesser extent, CB radio, were used effectively during the period of heaviest rain on August 2, particularly after commercial power and telephone channels failed. However, the total emergency radio system backup did not work as well as it could have, because of lack of sufficient organization.

As a part of the preparedness program, WSFO San Antonio has long had highly effective emergency communications through the San Antonio Repeater Organization, a group of dedicated amateur operators serving as storm spotters and flood reporters. An operating position is permanently installed at the WSFO and is manned by volunteer amateur radio operators as needed. The San Antonio Repeater Organization was particularly effective during this flood event. These amateurs set up emergency communications and provided WSFO San Antonio critical rainfall and river information after normal communications had failed. Amateur radio moved into Kerr County in the wake of the first flooding to set up emergency communications links of various kinds.

At Abilene the WSO has a permanent working arrangement with a local 2-meter amateur repeater club for storm spotting purposes. When the flooding occurred at Albany, a 2-meter amateur operator club from Graham, Texas, immediately moved into Albany and provided emergency communications into Abilene via the Abilene Club. Ironically, the Graham club had barely finished their mission at Albany when they had to return to Graham to provide emergency communications support to their home city because of major river flooding there.

## COMMUNITY DISASTER PREPAREDNESS

The National Weather Service has had for several years an active predisaster community preparedness program for all weather hazards. The overall objective is to save lives, reduce the number injured, and lessen the social and economic impact from all weather-related natural disasters. The preparedness program has contributed to the development of many local flash flood warning programs nationwide.

The program is carried out primarily through dedicated Disaster Preparedness Meteorologists (DPMs) at 18 WSFOs, including San Antonio and Fort Worth, and

the MIC/OICs of WSFOs and WSOs. The RFC and the Service Hydrologists at the WSFOs provide support in flash flood preparedness efforts.

These persons encourage preparedness planning and provide technical support and information on weather hazards and NWS emergency warning programs. Examples of these activities are:

1. Serve as technical consultant to ensure that preparedness plans are based on the realities of weather-related disaster threats and to provide understanding of NWS warning and dissemination capabilities.

2. Participate in preparedness meetings and public information sessions as an expert on natural disasters and NWS operations.

3. Provide training and advice in the establishment of flash flood and tornado spotter networks.

4. Encourage mass media to rapidly disseminate warnings and to publicize safety information to promote proper public response during emergency weather situations.

In the area struck by the flash floods, WSFOs San Antonio and Fort Worth, and WSO Abilene had undertaken an aggressive community disaster preparedness program. This has included tornadoes, flash floods, severe thunderstorms, river flooding, and for San Antonio, hurricanes.

At WSFO San Antonio, there has been excellent cooperation between the DPM and the Service Hydrologist in the flash flood preparedness effort and there has been considerable support from station management. During the past 9 months, WSFO San Antonio personnel have made at least 11 personal contacts in Kerr, Kendall, and Bandera Counties. These contacts have involved training storm spotters, replacing broken rain gages, installing new rain gages, and discussing and doing maintenance on the flash flood alarm system near Kerrville. At present, there are 12 local flash flood warning systems designed for specific flash flood vulnerable sites in the San Antonio warning responsibility area. One of these, for the City of Kerrville, was used to some extent during this episode.

The Kerrville plan was undergoing some modifications when the flooding occurred. For example, the flash flood alarm was about to be relocated from the police station to the fire station/CD office. Following the flood, the County Civil Defense director (who is also the Fire Chief and City Civil Defense Director) conducted a critique of the local flash flood warning system (WSFO San Antonio, local officials, and the media participating). Additional changes to the local plan will probably be made as the result of this and other actions.

According to the Kerrville Police Chief, there were problems with the Kerrville flash flood alarm (on the Guadalupe River). Its reliability was questioned several months before the flooding. The WSFO San Antonio staff checked the alarm system and found a tree had fallen across the alarm's phone line. The tree was removed and the alarm rechecked in early July.

On August 1, the alarm first sounded at 12:30 p.m. in response to the 5 to 7 inches of rain that had fallen during the preceding 12 hours. The police dispatcher relayed that information to some people on the warning call list, but not all. WSFO San Antonio issued its first warning based on this report. We don't know if the alarm sounded again on August 2 or if the alarm horn at the police station was turned off.

Since 1975, three local flash flood forecasting procedures have been developed for the Abilene County warning area: Snyder (scene of a disastrous flood in 1972), Brownwood, and Abilene. In this flooding episode, Abilene public safety officials used the system effectively, producing orderly and early evacuation of persons from threatened areas. Subsequent to the Albany flood, a Weather Service team visited Albany officials on September 25 to discuss development of a local flash flood forecasting procedure for that city. Work is now underway on such a system.

Public education is another important part of the preparedness program. To accomplish this, NWS offices work closely with local media (radio, television, newspaper) and schools to ensure that people understand the weather hazards that may affect them, the official advices they may receive, and the proper human/property safety measures they may have to take. WSFO San Antonio and WSO Abilene have been extremely active in this area. Since 1975, WSO Abilene has organized storm spotter groups in 9 of the larger towns in its 13-county warning area. For the last 3 years WSO Abilene has made annual mailings of preparedness literature to each school system and each school superintendent with personal followup visits or phone calls. Additionally, the WSO in each of the 3 years has contacted the County Judge and/or Civil Defense Director in each county concerning weather and flood hazards as well as NWS support in event of accidental spills of hazardous and toxic materials.

WSFO San Antonio held 44 meetings in its county warning area during the period January-July 1978. More than 1,650 people attended these meetings involving 12 of the 21 counties in San Antonio's area. A majority of these dealt with flash floods, severe thunderstorms, tornadoes, civil defense coordination, and school preparedness. One awareness meeting was held at the Medina Children's Home (about midway between Kerrville and Medina) in 1976. The people we interviewed at the Home remembered the meeting and much of the information given.

In the San Antonio area, radio and television stations broadcast some public weather safety information messages prior to the flooding. But for the most part, the stations we interviewed did not have prepared NOAA/NWS spots or press releases, although few did have civil defense weather safety spots. There are several reasons for this:

1. NOAA's Public Affairs Office does not have adequate funding to supply all 8,500 radio and TV stations nationwide. Most material goes to 700 TV stations and the largest radio stations.

2. The media receives great volumes of similar material from various government agencies and nonprofit organizations. There is a tendency to file much of it away and then forget it.

3. Even NWS offices with DPM staffing are not in a position to promote NOAA/NWS safety spots, because the spots are sent directly to the media. NWS offices do not review the spots beforehand.

We visited one Spanish-speaking television station. The station has NWWS and includes weather information at newstime. It does not have crawl capability. The station and, apparently, other Spanish-speaking stations (radio and television) don't broadcast NOAA's prerecorded weather safety spots because the English spots aren't accompanied by a written text (English or Spanish). However, earlier in the year WSFO San Antonio sent this TV station and others on the NOAA Weather Wire System the Spanish version of the publication "KILLER FROM THE HILLS," along with tornado and lightning safety information. The latter were also in Spanish.

In summary, the Texas NWS offices involved in this disaster have been very active in before-the-fact disaster preparedness and public education. It is important to note that very significant and noteworthy personal efforts have been made by NWS field personnel. Both DPMs, the MIC of WSO Abilene, and others have spent their own time and resources to visit communities, public service groups, and schools--the job simply cannot be done within the time and money resources available. And yet, it is frustrating to them that so much remains to be done.

## PUBLIC RESPONSE

Although flash flood watches and warnings were in effect many hours before the devastating flash floods in Kerr, Kendall, and Bandera Counties, 25 people died (plus 2 more in Gillespie County, which was not surveyed). The natural question to ask is, "Why so many?" After seeing the magnitude

of the flooding and destruction, it is remarkable that not more people died! Granting that the area is rather thinly populated, it is possible that another identical situation could kill a hundred or more people. Considering technical limitations, it is hard to conceive of the National Weather Service doing a much better overall job than it did. Would the NWS do as well next time? Advices were out early, and many public officials were aware of them. The watches and warnings were generally well written (see examples in Appendix A) and noted that the remnants of decaying Tropical Storm Amelia would bring localized heavy rains to the Texas Hill Country. They also reflected a highly unusual event and were, for the most part, geographically specific (i.e., they indicated what rivers/creeks would be most vulnerable).

Public officials and many individuals acted once they realized the extent of the developing disaster. Hundreds moved or were moved away from vulnerable areas. Many risked their lives to save others.

If warnings were out and public officials and many individuals were aware of them, why did anyone die? Two reasons seem probable:

1. First, not everyone received a warning in time. It is impossible for public officials to contact everyone and not everyone listened to radio or television.

2. Life-saving actions by public officials and others were generally not taken until the flood waters actually became a real threat. Why? Scientific and technical skill is not available to define accurately the magnitude, time of occurrence, and geographic location of each flash flood. We overwarn. During a typical year, NWS offices issue many flash flood watches and warnings, but few really serious flash floods occur. Further, relatively large areas are typically watched/warned for an extremely localized event. This tends to desensitize individual citizens and public officials to the danger. This situation is a direct result of our technical limitations. Many weather systems have the capability of producing serious flash flooding--but only a few do occur. We do not have the observing and forecasting tools to discriminate adequately between the two. Certainly, we do not now have the skill to say, "Here comes the storm of two or three centuries."

There are other possible reasons why some people may have died:

- o Vulnerability because of age: Many who died were either very young or quite old. In both cases, they presumably were less equipped to deal with the situation--particularly the old who probably were much less mobile and could not evacuate easily.

- o Fear of looting: Several people we interviewed were reluctant to leave their homes and/or businesses for fear of looting. Yet, there was very little reported looting.

- o Denial of danger: This normal sociological/psychological mechanism "protects" people from the reality of their peril. Comments such as "we've been here for years and we've had some flooding, but it's never gotten that bad," and "I never imagined the water could get that high" were typical responses. One elderly man reportedly went back to sleep even though his son urged him to evacuate and water was already in his bedroom.

- o Concern about property: One man died trying to save his cattle. At least two or three others reportedly died, because the family took too long loading the family car.

A subject receiving attention in past surveys is warning terminology. Do people know the difference between "watch" and "warning?" Although many people we interviewed could not fully define each term, most, with a little bit of effort, were able to explain the difference between them. There was widespread agreement that the media (especially radio) helped them understand the terms by constantly repeating the watches and warnings and the definitions they contained.

## FINDINGS AND RECOMMENDATIONS

### Finding 7.1

The broadcast media did an effective job of disseminating flash flood watches, warnings, and statements. Those who listened to TV or radio heard the NWS flash flood advices. We would estimate this includes about 50 percent of the population. Radio was especially effective in repeating weather information. The Kerrville radio station, KERV, and the Kerrville cable TV station both broadcast beyond normal operating hours.

### Recommendation 7.1

The media serving the area should be recognized for their exemplary performance during this event.

### Finding 7.2

Many Texas Hill Country people received no watch or warning information, because they were not listening to radio or watching TV. Others, including some public officials, received information later than they might have. NOAA Weather Radio could have played a substantial role because of its

positive alerting feature if the San Antonio broadcast could have reached into the affected areas. It could have delivered watches and warnings more rapidly than by other means. It could have saved lives.

Recommendation 7.2

NWR coverage in the Texas Hill Country should be included in any expansion of the network.

Finding 7.3

While it was not a factor in the dissemination of warnings to the Hill Country, the San Antonio NWR transmitter was knocked off the air by lightning for 2 hours during the storm. Such outages could be critical in future situations as NWR becomes more accepted as a warning medium.

Recommendation 7.3

If practical, standby power and increased lightning protection for all NWR transmitters in high lightning incidence areas should be provided.

Finding 7.4

The National Warning System (NAWAS) was used effectively to disseminate warnings and to solicit feedback from public officials. However, the Kerrville drop was knocked out for nearly 12 hours by flooding.

Recommendation 7.4

NWS should determine, with the Defense Civil Preparedness Agency, how to make NAWAS more fail-safe and look into possible alternative means of reaching public officials.

Finding 7.5

Expanded use by radio and TV stations of NOAA Public Affairs Office "spots" and press releases on weather emergencies would enhance public preparedness. For a number of reasons, this use is somewhat restricted.

Recommendation 7.5

NWS should review its support to the media and expand it where practicable. NOAA and NWS should also set up procedures for enlisting NWS field offices in promoting NOAA/NWS safety spots with radio and TV stations.

In making this recommendation we recognize that an increase in effort by other State and Federal groups will also produce greater demand for NWS preparedness assistance and support.

Finding 7.6

While the NWS had done considerable amount of outstanding work on community disaster preparedness in the flooded areas, personnel and financial resources available within the field offices are not sufficient to do all that needs to be done.

Recommendation 7.6

The community disaster preparedness effort needs more resources if the job is to be fully accomplished. Either more should be done by other agencies and groups at the Federal and State levels and/or NWS resources should be increased.

Finding 7.7

Many people delayed taking life-saving action because they did not feel sufficiently threatened by our warnings. A probable reason is that they had heard many warnings over the years that were not verified by their own observations.

Recommendation 7.7

NWS must constantly seek ways to make its warnings more specific and meaningful. (See "findings and recommendations" in earlier chapters.) In addition, the NWS should continue to encourage the most vulnerable communities and areas to establish locally operated flash flood warning systems and community preparedness plans. These can make communities more responsive to NWS warnings and can also self-activate the communities when required by localized conditions of which the NWS may not be aware. Flash flood alarms and high community involvement are but two of the most critical ingredients of such systems. (See Chapter 2 for discussion of flash flood alarms and community warning systems.)

Finding 7.8

EBS was not used by the media in the San Antonio area when requested. There was a distinct reluctance to do so.

Recommendation 7.8

Future NWS plans, policies, and procedures relative to the use of EBS should realistically reflect the deep reluctance of many broadcasters to use EBS for weather warnings.

# CHAPTER 8

# RIVER FLOODING AND FORECASTS

A prolonged 2-month drought and heat wave throughout much of Texas was abruptly ended by the torrential rains. In addition to producing tremendous flash floods, the heavy rains caused major flooding along numerous Texas rivers which had been running very low because of the drought. In many cases, flooding was so severe that rivers and streams rose to record or near-record stages. It was also widespread, occurring on the Nueces, Sabinal, Frio, Medina, San Antonio, Guadalupe, Pedernales, Llano, San Saba, Colorado, and Brazos Rivers. All of these rivers are within the area served by the Fort Worth RFC. During and following the storm, the RFC prepared and issued many flood warnings and forecasts to alert the public to this dangerous situation. The remainder of this chapter will describe the flood warning system and its performance during the Texas floods.

## THE FLOOD WARNING SYSTEM

The river and flood forecast and warning system operated by NWS functions through two echelons of forecast offices: RFCs and WSFOs/WSOs. The primary mission of the program is to save lives and prevent injuries, and to reduce property damage. This is accomplished by providing timely flood crest forecasts for key cities and points along river systems.

Flooding with a longer rise time and, hence, longer reaction time, generally is referred to as River Flooding. It is associated with larger streams and with situations where the longer rise time permits an orderly process of data collection and analysis to yield specific river stage forecasts.

Flood warnings usually indicate that flooding to a certain stage will occur at some point along a river at a specific time in the future. Hence the time between the issuance of a flood warning and the crest may range from several hours to several days. This lead time often permits people to take action to reduce flood damage and to evacuate themselves. Flood warnings and forecasts are initially prepared and issued by the RFC. The RFC depends upon WSFOs and WSOs for the collection and relay of river and rainfall data. Once a forecast has been issued by the RFC it is then disseminated by the appropriate WSFO/WSO to the public, the media, and other principal users via NWR, NWWS, and other means. RFCs also coordinate and relay flood warnings and forecasts directly with certain Federal and local agencies when appropriate.

The River Forecast Center is responsible for daily stage forecasts as well as flood warnings and forecasts for key points on the main stem and major tributaries of the river systems. Other RFC responsibilities

pertinent to this report include the technical lead in preparation of community flash flood warning systems and advice to WSFOs on flood potential. Similarly, WSFOs support the RFC as meteorological consultants. Typically, the WSFO has a Service Hydrologist on the staff to lead the hydrologic services program.

## CHRONOLOGY OF OPERATIONS AND FORECASTS

### August 1

Rainfall amounts ranging from 4 to 6 inches over several counties south and west of San Antonio began during the morning and early afternoon hours. As rainfall continued into the evening, the Fort Worth RFC added an evening shift to its normal operating hours of 7 a.m. to 5 p.m. CDT. Based on 7 p.m. rainfall reports, flood forecasts were issued for the Guadalupe, Sabinal, Frio, Atascosa, San Antonio, and Medina Rivers, and San Miguel Creek at 10:15 p.m. Flood forecasts called for rises to above flood stage, but could not anticipate the heavy rain which occurred during the next 6-12 hours.

### August 2

During the early morning hours, it became apparent to forecasters at WSFO San Antonio that very heavy rain was falling over the Hill Country. A phone call from SAT WSFO at 5 a.m. alerted RFC personnel to the flood problem. The RFC resumed operations at 5:45 a.m. Rainfall reports received before Hill Country communications went out about 6 a.m. prompted a 6:56 a.m. flood warning stating that major flooding was occurring in the headwaters of the Guadalupe, Medina, and Sabinal Rivers and that it would be moving downstream within the next few hours. Flood warnings were revised and reissued at 8:30 a.m. as more information became available. RFC and San Antonio WSFO personnel agreed that record flows might be occurring along these rivers, and this fact was emphasized in flood bulletins. Record flows were indeed occurring. The Guadalupe River at Comfort, Texas, crested at 40.8 feet (estimated peak discharge was 240,000 cubic feet per second) sometime between 7 a.m. and 9 a.m. on August 2. Bankfull there is 26 feet.

The previous flood of record was a stage of 40.3 feet, which occurred in 1869. On the Medina River near Pipe Creek, Texas, the flood crested shortly before noon on August 2 at 47 feet (estimated peak discharge was 280,000 cfs). Bankfull there is 10 feet, and the previous flood of record had been 43 feet in 1919.

As flash flooding ended during the morning, the RFC directed its attention toward downstream flood forecasts and reservoir inflows for Medina Lake on

the Medina River and Canyon Reservoir on the Guadalupe River. Revised forecasts for these rivers were issued at 4:15 and 11:30 p.m. During the course of the day, many additional forecasts had been issued for flooding along the Colorado, Llano, San Saba, and Pedernales Rivers. RFC and San Antonio hydrologists coordinated these forecasts with the Corps of Engineers, River Authorities, and the Texas DPS as new information and additional rainfall changed the situation.

August 3

Heavy rainfall that had begun again over the Upper Guadalupe Basin before midnight continued into the early morning hours. The RFC and SAT WSFO remained in touch during this period trying to obtain river stage and rainfall reports. Telephone lines to the Hill Country remained out of service. One report of an additional 14 inches of rain at Ingram, Texas, was finally verified at 5 a.m. Based on this report and MDR intelligence, a warning of an additional rise of major proportions was issued for the Upper Guadalupe from Kerrville to Spring Branch. As additional information became available during the morning, revised flood forecasts were issued for the Guadalupe, Medina, Sabinal, San Antonio, Llano, Pedernales, San Saba, Atascosa, Frio, and Nueces Rivers and San Miguel Creek. Some of these forecast points were in the local warning areas of the Austin and San Angelo WSOs.

Rainfall during the early morning had also spread northward. Several reports of 6 to 8 inches overnight were received from the Big Country near Abilene and Brownwood, Texas. This caused a sharp rise along Pecan Bayou above Brownwood Reservoir.

Following an afternoon of moderate but steady rain, torrential rains began to fall in the counties north and northeast of Abilene between 4 and 5 p.m., with the really heavy rains beginning in the Albany area about 6 p.m. This deluge continued until after midnight, producing a total of 32 inches near Albany in Shackelford County. However, this unofficial report was not known to the RFC until midafternoon, August 4, and could not be immediately verified. Real time heavy rainfall reports were not adequate to fully describe what was happening. Those reports that were available were quickly passed on.

August 4 Through August 7

Friday, August 4, began with a flourish of activity as reports of very heavy rain arrived from Shackelford, Jones, Haskell, and Throckmorton Counties in the Big Country. Based on a 17-inch rainfall report from Jones County, several other large totals, and MDR data, the RFC prepared a flood forecast for the Brazos River that was issued at 8:45 a.m. It stated a very sharp rise would occur along the Brazos River at Fort Griffin,

Texas, later that day with a crest near 35 to 36 feet. This early crest forecast was near the 1932 flood record of 38 feet. A revised flood forecast for the Brazos River calling for very high flows at or near Seymour, Hawley, Nugent, Fort Griffin, Eliasville, and South Bend was issued at noon on the 4th. This issuance also included a crest forecast 14 feet above flood stage on the Colorado River near Winchell, Texas. It was apparent that these floods would affect thousands of people and many communities, especially along the Brazos. The August 4 midafternoon report of 32 inches at Newell Oilfield, northwest of Albany, caused the RFC to revise upward the Fort Griffin forecast crest stage to 39 feet, a record for the gage. Further coordination that lasted for several days was initiated by the RFC with the Corps of Engineers, Brazos and Colorado River Authorities, and the Texas DPS. Inflow forecasts to Possum Kingdom Reservoir below South Bend on the Brazos became extremely important.

During the next several days, flood forecasts were revised as major flood crests continued to move down many rivers in both North and South Texas. Record flows occurred on the Brazos River at Fort Griffin, Eliasville, and South Bend. During the event, the RFC was called upon to provide forecasts for many points and situations for which forecasts had never before been prepared. As an example, the town of Graham in Young County, on a small creek several miles from the Brazos, was flooded by backwater from the Brazos River and Possum Kingdom Reservoir. Timely flood forecasts permitted many damage reduction actions to be taken in Graham. The county government decided not to evacuate critical documents from the County Courthouse based on an RFC forecast for the Courthouse itself. The forecast was correct as the rising water stopped within one-half block of the Courthouse.

An RFC-developed program that creates 6-hourly summed MDR values was valuable when observed rainfall reports were scarce. The RFC does not use the program to indicate the magnitude of rainfall, but rather for the areal and temporal distribution of what rainfall reports were available.

In general, the dissemination of flood forecasts by the media was very good. Public awareness of major floods moving downstream was keen in the aftermath of the tragic flash flooding.

## FINDINGS AND RECOMMENDATIONS

### Finding 8.1

The Fort Worth RFC provided outstanding public service during the Texas floods. It is likely that flood forecasts were responsible for saving lives (there were no deaths related to downstream flooding) considering the extent and magnitude of flooding. Timely forecasts allowed people

to save property and reduce damage. The small RFC staff of seven hydrologists maintained 24-hour operations from early morning on August 2 until midnight on August 7, and logged 176 hours overtime.

Recommendation 8.1

Appropriate commendations should be awarded.

Finding 8.2

A lack of real time river stage and rainfall data hindered RFC operations. There were no automated gages to interrogate as communications went out and river gages became inaccessible.

Recommendation 8.2

Flood warning programs, like flash flood programs, should be supported by automated gages with satellite and/or radio communications.

APPENDIX A

SELECTED WATCHES AND WARNINGS

SAN ANTONIO

BULLETIN

FLASH FLOOD WATCH
NATIONAL WEATHER SERVICE SAN ANTONIO TX
840 AM CDT TUE AUG 1 1978

THE NATIONAL WEATHER SERVICE HAS ISSUED A FLASH FLOOD WATCH FOR THE REMAINDER OF THIS MORNING AND THIS AFTERNOON FOR A PORTION OF SOUTH CENTRAL AND SOUTH TEXAS. THE AREA WHICH WILL EXPERIENCE THE GREATEST THREAT OF FLASH FLOOD PRODUCING RAINS IS ALONG AND ABOUT 50 MILES EITHER SIDE OF A LINE EXTENDING FROM LAREDO TEXAS TO AUSTIN TEXAS.

THE REMAINS OF TROPICAL STORM AMELIA HAVE BECOME ABOUT STATIONARY OVER SOUTH TEXAS IN THE AREA TO THE WEST OF AUSTIN AND SAN ANTONIO. INSTABILITY ASSOCIATED WITH THE DYING STORM IS PRODUCING WIDESPREAD RAINS AND THUNDERSTORMS OVER A LARGE PORTION OF SOUTH TEXAS.

DURING THE NIGHT RAINS OF ONE INCH OR MORE HAVE OCCURRED OVER MUCH OF THE WATCH AREA. SOME ACCUMULATIONS OF SLIGHTLY OVER FIVE INCHES HAVE BEEN REPORTED JUST TO THE NORTHEAST OF SAN ANTONIO.

WITH THE GROUND NOW BECOMING SATURATED...ADDITIONAL HEAVY RAINS MAY PRODUCE FLASH FLOODING ALONG STREAMS...CREEKS AND RIVERS IN THE WATCH AREA. MOTORISTS SHOULD BE PARTICULARLY CAUTIOUS WHEN APPROACHING LOW WATER CROSSINGS AND PERSONS NEAR WATERWAYS SHOULD BE PREPARED FOR QUICK ACTION IN THE EVENT FLASH FLOOD WARNINGS ARE REQUIRED.

EVERYONE IS URGED TO LISTEN TO RADIO OR TELEVISION STATIONS OR TO MONITOR NOAA WEATHER RADIO FOR THE LATEST INFORMATION ON THE CURRENT WEATHER SITUATION.

ADDITIONAL STATEMENTS WILL BE ISSUED AS CONDITIONS WARRANT.

FLASH FLOOD STATEMENT
NATIONAL WEATHER SERVICE SAN ANTONIO TX
1130 AM CDT TUE AUG 1 1978

...A FLASH FLOOD WATCH CONTINUES IN EFFECT THIS AFTERNOON FOR A LARGE PART OF SOUTH CENTRAL AND SOUTH TEXAS...

THE REMNANTS OF TROPICAL STORM AMELIA ARE CONTINUING TO PRODUCE WIDESPREAD RAINS OVER SOUTH TEXAS. SHORTLY AFTER 11 AM THIS MORNING AN AREA OF RAIN ABOUT 150 MILES WIDE EXTENDED FROM THE AUSTIN.. JUNCTION AREA SOUTHWARD TO THE RIO GRANDE. WITHIN THIS AREA RADAR WAS SHOWING HEAVY SHOWERS AND THUNDERSHOWERS OVER SOUTHERN BEXAR AND NORTHERN ATASCOASA COUNTIES...OVER PORTIONS OF MEDINA AND FRIO COUNTIES..AND OVER PARTS OF UVALDE..REAL..BANDERA AND KERR COUNTIES.

GENERAL RAINS OF ONE INCH OR MORE HAVE OCCURRED OVER MOST OF SOUTH CENTRAL TEXAS DURING THE NIGHT AND PARTS OF NORTHEAST BEXAR.. COMAL..AND EASTERN KERR COUNTIES HAVE RECEIVED MORE THAN FIVE INCHES. KNIPPA IN EASTERN UVALDE COUNTY HAS ACCUMULATED MORE THAN THREE INCHES SINCE 8 AM THIS MORNING.

WITH THE GROUND NOW SATURATED...ADDITIONAL RAPID ACCUMULATIONS OF RAINFALL WILL CAUSE FLASH FLOODING ALONG CREEKS..STREAMS AND RIVERS MANY OF WHICH ARE NOW RUNNING BANKFULL. ALL PERSONS IN THE WATCH AREA WHICH INCLUDES THE AREA ALONG AND ABOUT 50 MILES EITHER SIDE OF A LINE FROM LAREDO TO AUSTIN...SHOULD REMAIN ALERT FOR HEAVY RAINS AND RAPIDLY RISING WATER AND SHOULD MONITOR RADIO AND TELEVISION STATIONS FOR POSSIBLE FLASH FLOOD WARNINGS.

ADDITIONAL STATEMENTS WILL BE ISSUED AS REQUIRED.

BULLETIN EBS ACTIVATION REQUESTED
FLASH FLOOD WARNING
NATIONAL WEATHER SERVICE SAN ANTONIO TX
1255 PM CDT TUE AUG 1 1978

THE NATIONAL WEATHER SERVICE HAS ISSUED A FLASH FLOOD WARNING FOR THE GUADALUPE RIVER IN KERR COUNTY TEXAS VALID UNTIL 4 PM CDT THIS TUESDAY AFTERNOON.

HEAVY RAINS OF UP TO FOUR INCHES FELL DURING THE NIGHT ON THE WATERSHED OF THE GUADALUPE AND ADDITIONAL RAINS OF NEAR TWO INCHES HAVE FALLEN SINCE 7 AM THIS MORNING.

FLASH FLOODING ALONG THE GUADALUPE DOWNRIVER FROM INGRAM WILL LIKELY TAKE PLACE DURING THE AFTERNOON. PERSONS NEAR THE RIVER SHOULD MOVE TO HIGHER GROUND IMMEDIATELY.

BULLETIN
FLOOD WARNING FOR THE UPPER GUADALUPE RIVER
NATIONAL WEATHER SERVICE SAN ANTONIO TX
1 PM CDT MON AUG 1 1978

KERRVILLE HAS HAD 5.50 INCHES OF RAINFALL AND IT CONTINUES TO RAIN IN THAT AREA...OTHER AMOUNTS OF RAINFALL IN THE AREA...HUNT 4.00 INCHES...INGRAM 4.26 INCHES AND 10 MILES WEST OF HUNT 2.00 INCHES.

THE FLASH FLOOD ALARM HAS SOUNDED IN KERRVILLE IN THE PAST 30 MINUTES INDICATING A SHARP RISE IS MOVING DOWN THE RIVER FROM INGRAM TO KERRVILLE. THIS RISE IS EXPECTED TO CREST NEAR 8 FEET IN KERRVILLE AND THIS IS 5 FEET OVER BANKFULL ....THIS RISE WILL CREST IN THE KERRVILLE AREA AT MIDAFTERNOON MOVE DOWN STREAM TO COMFORT AND SPRING BRANCH LATER TONIGHT.

ALL PERSONS ALONG THE GUADALUPE RIVER SHOULD BE ALERT FOR RISING WATER. MOTORISTS SHOULD USE EXTREME CAUTION ON LOW BRIDGES AND LOW WATER CROSSINGS ON THE RIVER AND SMALL STREAMS IN THE KERRVILLE AREA. LIVESTOCK SHOULD BE MOVED TO HIGHER GROUND AS SOON AS POSSIBLE FROM THE FLOOD PLAIN OF THE GUADALUPE RIVER.

BULLETIN

FLASH FLOOD WATCH
NATIONAL WEATHER SERVICE SAN ANTONIO TX
250 PM CDT TUE AUG 1 1978

THE NATIONAL WEATHER SERVICE HAS EXTENDED A FLASH FLOOD WATCH FOR A LARGE PORTION OF SOUTH CENTRAL AND SOUTHWEST TEXAS TO BE VALID THROUGH TONIGHT. THE WATCH AREA HAS BEEN ADJUSTED SLIGHTLY AND NOW MAY BE DESCRIBED AS ALONG AND ABOUT 70 MILES EITHER SIDE OF A LINE EXTENDING FROM EAGLE PASS TO GEORGETOWN TEXAS. THIS AREA INCLUDES THE AUSTIN AND SAN ANTONIO METROPOLITAN AREAS AS WELL AS MOST OF THE TEXAS HILL COUNTRY.

WITHIN THE WATCH AREA GENERAL RAINS OF ONE TO THREE INCHES HAVE FALLEN TODAY WITH SOME AREAS RECEIVING VERY LARGE ACCUMULATIONS. KERRVILLE HAS RECEIVED ALMOST SEVEN INCHES OF RAIN SINCE MIDNIGHT AND A NUMBER OF LOCATION JUST TO THE NORTH AND NORTHEAST OF SAN ANTONIO HAVE HAD MORE THAN FIVE INCHES.

AT 230 PM HEAVY RAINS WERE DEVELOPING IN THE AUSTIN AREA AND AS NIGHTFALL APPROACHES...COOLING AT HIGH LEVELS IN THE ATMOSPHERE WILL CAUSE INCREASING INSTABILITY AND THE POSSIBILITY OF HEAVY RAINS REDEVELOPING OVER THE HILL COUNTRY WILL REMAIN.

MANY STREAMS AND RIVERS ARE NOW RUNNING BANKFULL AND ANY ADDITIONAL HEAVY RAIN WILL CAUSE RAPID RISES. ALL PERSONS IN THE WATCH AREA ARE URGED TO KEEP IN TOUCH WITH FUTURE DEVELOPMENTS AND BE READY FOR QUICK ACTION IN THE EVENT FLASH FLOOD WARNINGS ARE REQUIRED.

BULLETIN - IMMEDIATE BROADCAST REQUESTED
FLASH FLOOD WARNING
NATIONAL WEATHER SERVICE SAN ANTONIO TX
7 PM CDT TUE AUG 1 1978

THE NATIONAL WEATHER SERVICE HAS ISSUED A FLASH FLOOD WARNING EFFECTIVE UNTIL 11 PM CDT FOR PERSONS IN ATASCOSA...FRIO...MEDINA...WILSON... GUADALUPE...COMAL...KENDALL...BANDERA...KERR AND BEXAR COUNTIES OF TEXAS...INCLUDING THE SAN ANTONIO METROPOLITAN AREA.

A FLASH FLOOD WARNING MEANS FLOODING IS IMMINENT. TAKE NECESSARY PRECAUTIONS IMMEDIATELY.

HEAVY RAIN WAS INDICATED BY RADAR FROM SOUTHERN BEXAR COUNTY INTO FRIO AND ATASCOSA COUNTIES TO THE SOUTH OF SAN ANTONIO. THESE HEAVY RAINS ARE MOVING TOWARDS THE NORTH AT ABOUT 20 MPH.

SINCE GROUNDS ARE ALREADY SOAKED AND CREEKS AND RIVERS SWOLLEN WITH PREVIOUS HEAVY RAINS...RAPID RUNOFF AND THE GREAT THREAT OF FLASH FLOODING IS INCREASED.

PERSONS CLOSE TO FLOOD-PRONE CREEKS AND RIVERS SHOULD TAKE IMMEDIATE ACTION TO MOVE TO HIGHER GROUND. MOTORISTS SHOULD AVOID LOW-WATER CROSSINGS WHEREVER POSSIBLE AND ROADS SUSCEPTIBLE TO RISING WATER AND FLOODING.

BULLETIN EBS ACTIVATION REQUESTED
FLASH FLOOD WARNING
NATIONAL WEATHER SERVICE SAN ANTONIO TX
515 AM CDT WED AUG 2 1978

URGENT...

THE NATIONAL WEATHER SERVICE HAS ISSUED AT FLASH FLOOD WARNING FOR THE GUADALUPE RIVER AND ALL ITS TRIBUTARIES IN KERR AND KENDALL COUNTIES..BOTH IN TEXAS. THIS WARNING WILL BE IN EFFECT UNTIL 10 AM CDT THIS WEDNESDAY MORNING.

DEPART OF PUBLIC SAFETY REPORTS THAT BETWEEN 12 AND 14 INCHES OF RAIN HAVE FALLEN ON THE SOUTH FORK OF THE GUADALUPE SINCE MIDNIGHT. WITH THE VERY HEAVY RAINS OF MONDAY...THIS WILL CAUSE EXTRAORDINARY FLASH FLOODING ON THE RIVER IN KERR AND KENDALL COUNTIES.

EVERYONE IS URGENTLY ENCOURAGED TO GET AWAY FROM THE GUADALUPE RIVER AT ONCE...ESPECIALLY IN THE CITIES OF HUNT..INGRAM..KERRVILLE AND ON DOWN RIVER. THIS APPEARS TO BE A CRITICAL SITUATION AND VERY SERIOUS FLASH FLOODING WILL BE MOVING DOWN THE GUADALUPE THROUGH KERR AND KENDALL COUNTIES.

PLEASE GET AWAY FROM THE GUADALUPE RIVER AT ONCE.

BULLETIN...EPS ACTIVATION REQUESTED
FLASH FLOOD WARNING
NATIONAL WEATHER SERVICE AUSTIN TX
7000 AM CDT WED AUG 2 1978

THE NATIONAL WEATHER SERVICE HAS ISSUED A FLASH FLOOD WARNING EFFECTIVE UNTIL NOON TODAY..FOR PERSONS IN GILLESPIE AND BLANCO COUNTIES OF CENTRAL TEXAS.

A FLASH FLOOD WARNING MEANS FLOODING IS IMMINENT AND NECESSARY PRECAUTIONS SHOULD BE TAKEN.

HEAVY RAINS WERE INDICATED BY RADAR AND REPORTED BY OBSERVERS AT BOTH STONEWALL AND FREDERICKSBURG EARLY THIS MORNING.

A STAGE OF 8 AND 1/2 FEET WAS REPORTED WHICH IS NEAR FLOODSTAGE AT STONEWALL. THESE FLOOD WATERS ARE MOVING DOWN THE PEDERNALES TOWARD JOHNSON CITY AND EVENTUALLY INTO LAKE TRAVIS. PERSONS ALONG THIS STREAM AND ADJACENT TRIBUTARIES SHOULD BE READY FOR FLOODING.
VERY HEAVY RAINS CONTINUE OVER PARTS OF THE TEXAS HILL COUNTRY WEST OF AUSTIN...ESPECIALLY ALONG AND SOUTH OF THE COLORADO RIVER WATERSHED.

LISTEN TO NOAA WEATHER RADIO..OR LOCAL RADIO AND TV STATIONS FOR LATER STATEMENTS AS THEY BECOME NECESSARY.

WSFO FORT WORTH

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE FORT WORTH TX
1030 AM CDT THU AUG 3 1978

THE NATIONAL WEATHER SERVICE AT FORT WORTH HAS SHIFTED THE FLASH FLOOD WATCH IN NORTH TEXAS TO THE WICHITA FALLS ABILENE AREA FOR THIS AFTERNOON AND TONIGHT. THE WATCH IF NOW FOR THE NORTH TEXAS AREA WEST OF A LINE THROUGH WICHITA FALLS EASTLAND BROWNWOOD AND JUNCTION TEXAS.

MORNING SATELLITE PICTURES SHOWED THE TALLEST STORMS AND THOSE PRODUCING THE MOST RAIN WAS OVER THE AREA BETWEEN ABILENE AND JUNCTION. THE EASTERN EDGE OF THE RAIN AREA WAS AT NACONE WEATHERFORD STEPHENVILLE AND BRADY AND WAS RETREATING WESTWARD AWAY FROM THE METROPLEX AREA.

SIX TO EIGHT INCHES OF RAIN FELL DURING THE PAST 24 HOURS BETWEEN ABILENE AND BROWNWOOD. THE RAIN HAS FED WATER INTO STREAMS THAT HAD BEEN DRY FOR SEVERAL MONTHS AND A FEW RURAL ROADS ARE REPORTED TO BE UNDER WATER AT STREAM CROSSINGS.

UP TO SIX INCHES ADDITIONAL RAIN MAY FALL IN THE BIG COUNTRY AREA AROUND ABILENE THIS AFTERNOON AND TONIGHT. THE EXPECTED RAINS WILL BE SUFFICIENT TO CAUSE FLASH FLOODING TO OCCUR.

STAY TUNED TO YOUR FAVORITE RADIO STATION FOR PROGRESS REPORTS ON THE FLOOD THREAT.

WSO ABILENE

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE FORT WORTH TX
1230 AM CDT THU AUG 3 1978

THE NATIONAL WEATHER SERVICE AT FORT WORTH HAS SHIFTED THE FLASH FLOOD WATCH IN NORTH TEXAS TO THE WICHITA FALLS ABILENE AREA FOR THIS AFTERNOON AND TONIGHT. THE WATCH IF NOW FOR THE NORTH TEXAS AREA WEST OF A LINE THROUGH WICHITA FALLS EASTLAND BROWNWOOD AND JUNCTION TEXAS.

MORNING SATELLITE PICTURS SHOWED THE TALLEST STORMS AND THOSE PRODUCING THE MOST RAIN WAS OVER THE AREA BETWEEN ABILENE AND JUNCTION. THE EASTERN EDGE OF THE RAIN AREA WAS AT NOCONA WEATHERFORD STEPHENVILLE AND BRADY AND WAS RETREATING WESTWARD AWAY FROM THE METROPLEX AREA.

SIX TO EIGHT INCHES OF RAIN FELL DURING THE PAST 24 HOURS BETWEEN ABILENE AND BROWNWOOD. THE RAIN HAS FED WATER INTO STREAMS THAT HAD BEEN DRY FOR SEVERAL MONTHS AND A FEW RURAL ROADS ARE REPORTED TO BE UNDER WATER AT STREAM CROSSINGS.

UP TO SIX INCHES ADDITIONAL RAIN MAY FALL IN THE BIG COUNTRY AREA AROUND ABILENE THIS AFTERNOON AND TONIGHT. THE EXPECTED RAINS WILL BE SUFFICIENT TO CAUSE FLASH FLOODING TO OCCUR.

STAY TUNED TO YOUR FAVORITE RADIO STATION FOR PROGRESS REPORTS ON THE FLOOD THREAT.

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE FORT WORTH TX
430 PM CDT THU AUG 3 1978

A FLASH FLOOD WATCH CONTINUES OVER THE WESTERN PORTION OF NORTH TEXAS FOR TONIGHT WITH UP TO FOUR INCHES OF NEW RAIN POSSIBLE. THE AREA IS WEST OF A LINE THROUGH WICHITA FALLS EASTLAND BROWNWOOD AND JUNCTION TEXAS. THE AREA JOINTS UP WITH OTHER FLASH FLOOD AREAS BEING WATCHED IN SOUTH AND WEST TEXAS.

DURING THE DAY TODAY RAIN HAS CONTINUED OVER THE WATCH AREA BUT THE INTENSITY OF THE RAIN HAS DECREASED. THE STORMS ARE EXPECTED TO INCREASE IN STRENGTH AND NUMBER DURING TONIGHT. UP TO FOUR INCHES OF NEW RAIN ARE POSSIBLE IN THE WATCH AREA OF NORTH TEXAS TONIGHT. CONDITIONS ARE SUCH THAT THERE IS A HIGH POTENTIAL FOR FLASH FLOODING.

STAY TUNED TO YOUR FAVORITE RADIO STATION FOR PROGREGG REPORTS ON THE FLOOD THREAT ISSUED BY THE NATIONAL WEATHER SERVICE.

BULLETIN
FLASH FLOOD WARNING
EBS ACTIVATION REQUESTED
NATIONAL WEATHER SERVICE ABILENE TX
840 PM CDT AUG 3 1978

A FLASH FLOOD WARNING IS IN EFFECT UNTIL MIDNIGHT FOR PERSONS IN SHACKELFORD COUNTY OF NORTH TEXAS.

A FLASH FLOOD WARNING MEANS FLOODING IS IMMINENT OR HAS BEEN REPORTED. TAKE NECESSARY PRECAUTIONS AS REQUIRED.

FLASH FLOODING WAS REPORTED BY THE DEPARTMENT OF PUBLIC SAFETY IN ALBANY TX AT 840 PM CDT. ALSO RADAR INDICATED HEAVY RAINS IN THE AREA AND THEY ARE EXPECTED TO CONTINUE FOR ABOUT AN HOUR.

## APPENDIX B

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ABI | Abilene, Texas, Weather Service Office |
| AFB | Air Force Base |
| AFC | Automatic Frequency Control |
| AHOS/S | Automatic Hydrologic Observing System/Satellite |
| AMOS | Automatic Meteorological Observing System |
| AP | Associated Press |
| AUS | Austin, Texas, Weather Service Office |
| DCPA | Defense Civil Preparedness Agency |
| DID | Data Insertion Device |
| DPS | Texas Department of Public Safety |
| D/RADEX | Digitizer/Radar Data Experiment |
| EBS | Emergency Broadcast System |
| EQIR | Equivalent Infrared Satellite Image |
| FAA | Federal Aviation Administration |
| FTW | Fort Worth, Texas |
| GOES | Geostationary Operational Environmental Satellite |
| LFM | Limited Fine Mesh Atmospheric Model |
| MDR | Manually Digitized Radar Data |
| MFM | Movable Fine Mesh Atmospheric Model |
| MIC | Meteorologist-in-Charge |
| MOS | Model Output Statistics |
| NAS | Naval Air Station |
| NAWAS | National Warning System |
| NESS | National Environmental Satellite Service |
| NHC | National Hurricane Center |
| NMC | National Meteorological Center |
| NOAA | National Oceanic and Atmospheric Administration |
| NSSFC | National Severe Storms Forecast Center |

| | |
|---|---|
| NWR | NOAA Weather Radio |
| NWS | National Weather Service |
| NWWS | NOAA Weather Wire Service |
| OIC | Official-in-Charge |
| PA | Principal Assistant |
| PE | Primitive Equation Atmospheric Model |
| POP | Probability of Precipitation |
| PoPA | Probability of Precipitation Amount |
| QPB | Quantitative Precipitation Branch |
| QPE | Quantitative Precipitation Estimates |
| QPF | Quantitative Precipitation Forecasts |
| RADAP | Radar Data Processor |
| RAWARC | Radar Report and Warning Coordination |
| RFC | River Forecast Center |
| ROBEPS | Radar Operating Below Performance Standards |
| SAT | San Antonio, Texas, Weather Service Forecast Office |
| SD | Radar Report Message |
| SFSS | Satellite Field Services Station |
| SIM | Satellite Interpretation Message |
| TLETS | Texas Law Enforcement Teletypewriter System |
| UPI | United Press International |
| VHF | Very High Frequency |
| VIP | Video Integrator and Processor |
| WBRR | Weather Radar Remote |
| WSFO | Weather Service Forecast Office |
| WSMO | Weather Service Meteorological Office |
| WSO | Weather Service Office |
| WSOM | Weather Service Operations Manual |

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